
HEY THERE!
HOT ENUF
FOR YA?
SPECIAL
PHOENIX
MELTDOWN
ISSUE

September 1987

APA-TECH #55

The 555 Times #55

(Jeez, that's a lotta fives in one masthead!!)

The Amateur Press Association for the Members of

GENERAL TECHNICS

(if you can believe that...)

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Table of Conflagrants

N.B.:

(not burned)

1. Minac is two pages every four months. The copy count continues to be thirty.
2. The deadline for APA-TECH #56 shall be Thursday, October 1st in Kalamazoo.
3. We regret the necessity of dropping Sam Paris at this time. We hope to hear from him again soon.
4. If you owe or are low on money in your account, please send some in to your Friendly Editors (or we may find Ourselves constrained to reveal Our Darker Sides...)

Here I am again, hashing out more APA stuff in a hotel room and hoping to find a copy shop open on a weekend. This is the anniversary of our shift to monthly publication, which I'd say has been something of a success. I hope we'll manage to continue this and see the APA into many years to come. Well, I'm missing the convention, so I'm getting outta here. Cheer-o!

Stal.

ROASTER

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MOSTLY MAILING COMMENTS

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Included in this APA is a postcard map made by Covert Beach, one of our Geography students and a fan. I thought it was appropriate for the issue coming out for worldcon.

As you can see above, I have changed my mailing address. I am almost finished with my thesis but need to stay at school for a few more months while I finish. I did not want to renew my lease for another year, so I have campus housing.

MAILING COMMENTS FOR APATECH #54

Driving back from the wonderful berserker in the U.P. with Kathy Ford, I was reading to her from apatech #54. I wanted to frank her comments to Joa.

Joa:(from Kathy Ford) re your comment about the ignorance of the American public concerning the status of Puerto Rico: most people learn their geography from athletic events such as the Olympics. Puerto Rico fields and Olympic team, therefore it seems to be a totally independent country when it is actually a commonwealth 'freely associated with the U.S.' according to my desk encyclopedia.

This strange status was brought to my attention when a friend of mine decided that he wanted to represent Puerto Rico in the Winter Olympics in Sarajevo. You must understand that George never thought of himself as an athlete. He just realized that he was eligible, having been born in Puerto Rico, and that he would have no serious competition for a spot on the team. George lived in Albany, New York, a relative stone's throw from the winter sports complex at Lake Placid so he had access to practice facilities. He decided the luge was the sport for a self-avowed klutz and so spent the winter of '83 learning how to manage the beastly little sleds.

Puerto Rico was very happy to send him a flag to carry in the parade (he was the sole member of the Puerto Rican 1984 Winter Olympic Team) as long as he payed all his other expenses. George's strategy was to loose weight so that he wouldn't pick up too much speed on the luge run, be conservative, and hang on tight. The strategy worked as he finished third last when two hotshots fell off their sleds and were disqualified. His little adventure gave our group in Albany a special interest in the Winter Olympics and left George with enough stories to last at least several months.

Rod: thanks for encouraging map reading among the group. How about Hell, and Climax, Michigan. * re: readiness for war. In Trillion Year Spree, Brian Aldiss wonders if being prepared for the next war just makes it easier for the war to start.

Bill H: I heard on NPR that the Soviets are working on a solar reflector mirror over Moscow to eliminate the necessity of street lights at night. This sounds pretty far-fetched to me. Would it work?

Bob T.: I think you mean the Shedd Aquarium in Chicago. Did you get to the planetarium?

Guy C.: Interesting story idea. I read an article recently (I forgot the source) that said that about 10-13% of the population is gay, about 25% are straight and the rest are somewhere in-between, bi-sexuals, for example. I believe in Egypt and some other middle eastern countries, sex before marriage is forbidden so homosexuality is considered proper for singles.

Dave P: re yr cm to John Hall: You probably never heard of her because she was a woman. Our society, until recently, with few exceptions, has ignored the achievements of women. History is written by white men about white men. I have always felt cheated by the lack of women role models, especially in the sciences. Also, the comment about her leaving her family probably would not have been mentioned if the story was about a man. Stories abound of male explorers leaving family behind to tackle the rigors of ...etc.

Guy W.: re yr berserker: WOW! TERRIFIC! GREAT! WHEN WILL MY HEARING COME BACK?

Now, I want to throw something out to the floor (Yes, I'll pick it up later). Question: If you were forced to live in a universe from a book or short story, which one would you choose? Which ones would you just like to visit?

I find this question a problem because there are very few happy, easygoing places that are written about. Without some conflict, there wouldn't be much of a story.

TRANSPORTER TOPICS

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Number 49

For the Double-Nickel Issue

Mailing Comments

Notes From the Chair : It has been a busy summer around here, too. *

Onward! : My Dad knows people from all over the state and keeps getting gifts from hunters of various types of wild meat. Never had kangaroo patties, though. * I got to see the giant squid at the Smithsonian a couple of years ago on my way to ConStellation. Yes, they do get rather large. * We had a fannish Fourth at a friend's house in Lexington, complete with six year old girl. My Dad had just returned from a trip to Florida and had brought me some fireworks from Tennessee. * You drafting table reminds me of those used by the Cartographic Section where I work. * I had seen Star Sculptures but didn't know what they were called. *

Easton Comments : Your comments on homosexuality remind me of a story where people checked into a resort hospital to come down with mild versions of various diseases for their vacation. In the future people may change their sexual orientation as a fashion. Perhaps we may even be able to fall in love artificially. * Re. Yr. Cmnt. Crumbcrunchers, it is possible by looking at a map of Kentucky to determine the nationality of whoever settled there, simply by the place names. *

Technical Man : Welcome back. * That's not as bad as some people who believe that New Mexico (the state) is part of Mexico (the country). * I once heard a man on ten meters, using a portable rig in his car, complaining about the traffic jam he was in. The traffic jam was in California. Ranges with low-power tranceivers can be impressive, depending on conditions and frequency. Do you have an impedance matching device? Yeah, I am very familiar with those moans, buzzes and chirps, but didn't know what they were collectively called. *

Dr. Gonzo : I have never in my life been that organized. Impressive. * Re. Yr. Cmnt. Greg : I am sure that you meant oxygen and <u>helium</u>, instead of hydrogen. * I have taken the GRE twice. The first time I did great, scoring in the 93rd percentile. When I tried to get into graduate school they made me

take it again, and I did even better. I like to claim that I am 93rd percentile in test-taking skills. * Island cultures don't have low-tech so much as very sophisticated low-science. Ship-building, for instance, is a technology which many islanders are very good at, within the limitations of their resources (no nails or screws, for instance). *

On the Road Again : There was recently an article on the Canadian Tundra in (I believe) Natural History, which went into some detail on frost heaving and related phenomena. * The dog was barking to greet you. They do that. * This is the sort of trip you shouldn't do on the spur of the moment, but train for a month or two in advance. *

Me: Re. My Cmnt. Re. comets, I should have said "gas" instead of "dust." The sublimated gasses around the coma are the last thing to settle back onto the nucleus. These have a high proportion of water and other materials which are shiny when frozen in fine crystals, so as a comet leaves or enters a system is is very shiny. Or am I missing something here? *

Crumbcrunchers : Cats are fine... all three-and-a-half of them. (A fifteen pound tom counts as one-and-a-half.) Want one? * Re. Yr. Cmnt. Kiran : My favorite Christmas music is Beethoven's Ninth Symphony. * "Project A-ko" is a Japanese animated feature which opens in the near future, then advances to about twenty years further along. It is extremely funny, especially the penultimate gag, where you meet A-ko's parents. Even people who don't like animation in general seem to like this. *

Shameless Minac : Hmmmm, I don't read "Grimjack" but maybe I'll check this particular issue out. * Techie-talkies *again*? (Or is it still?) *

Quarter Zine : I just love all this inside information. * Considering the recent progress on arms talks, a joint US/USSR mission doesn't seem all that unfeasible. It's desirability is another matter. I do favor the co-op plan. Columbus didn't design a new type of ocean vessel for his explorations but used something developed for use closer to home and modified as people began making longer trips. I am a Planetary Society member and I can tell you just from reading the organization's own publication that not everyone in the group is in favor of Sagan's plans. * Re. Yr. Cmnt. Me : I've never heard of such a ridiculous suggestion! :-) * R. Yr. Cartoon : You know, don't you, that too much fluorine causes your teeth to turn brown and soft. * Re. Yr. Cmnt. Annette : We <u>are</u> intellectuals; we just specialize in the "hard" areas. I disagree about Gould's *Mismeasure of Man*. He seems polite and restrained, even excusing their incorrect results by showing that <u>everyone</u> on those eras was doing the same thing and no one had any reason to think that they were wrong. See above about my test taking skills. *

Summer Tech : Re. Yr. Cmnt. Me : I believe Roy Underhill makes a similar comment in one of his "Woodright's Shop" books. The old stuff which is still around is good quality because the bad quality stuff didn't last. *

Rivercon

This was a big hit this year. The high spot of the official events was a woman in a bird costume of Worldcon quality. It was marvelous. I did run into Kiran, but we only got to talk for a few minutes. I ate well, slept well (despite the morning wakeup call - the calliope on the Belle of Louisville) and had a lot of fun. I didn't do any gaming, but since that is one of my weekly activities didn't miss it. I baked a batch of my fablious Toll House Cookies Friday morning and despite careful rationing they were gone by Saturday afternoon. Didn't buy much; in fact, except for the hotel bill this was one of my cheapest cons. My room, by the way, was on the second floor, near the restaurant. I didn't even know they <u>had</u> rooms there. The bed was "hotel kingsize" which means that it was five feet wide and five feet long. I had to sleep diagonally, as usual. More of you should come to Rivercon.

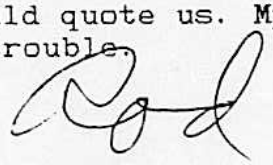
Sailing

Keith, a fannish friend of mine in Lexington (the system operator for the US Med Center's computers) recently bought a used sailboat. I had been invited to come out for a day of sailing on Cave Run lake and finally took him up on it on Saturday, August 22. As you may recall from the weather reports, this was the hottest day in Kentucky this year. We didn't notice; we were too busy trying not to capsize.

Keith, Carl (another fan) and I were out for about four hours. Thanks to internal and external sunscreen I didn't burn, and in fact had redness only on my chest just under the collarbone. The wind was strong, gusting and fickle, which made it difficult to retrieve Keith's hat when it blew off. We finally had to use the motor. Normally, the air is so light on Cave Run that one person handles both tiller and trimline. That day, Keith spent most of his time on the tiller and I manned the line. My job was to release the sail if we started over, which would remove the forces tilting us. I had to perform this task a number of times. Not everyone out sailing did this; we saw one boat go up on it's beam ends, the keel coming almost completely out of the water. I must have done my job well, 'cause they've invited me back.

General Notes

My boss and I may both be in trouble. A woman from Versailles came by to ask us about the proposed Versailles ByPass. She had read the Lexington paper that it was expected to carry 24,000 trips per day. My boss told her that the two major roads in the area didn't carry that much traffic together. She then asked where the figures had come from. I brought out the two forms we had received requesting information on the project, then explained to her that we had not done any work on these yet because of prior commitments. She talked with my boss for a while, then asked if she could quote us. My boss told her yes. Like I said , we may be in trouble.



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Nothing like being bludgeoned into submission...or is that submitting? Oh well, here I am at any rate.

Summer has been pretty easy this year. I've been doing secretarial work for my company during the days, and all but 1 of my evening classes is on break. In Aug. I'll be teaching 4 nights and 5 days, for a total of 23 teaching hours a week. This will be the most hours I've had at a time. As a rule I spend as much time out of class preparing as I spend in class. By Dec. I'll be ready for a long vacation.

The general idea is that all funds obtained from the office work will cover our expenses for a trip to the States this Christmas. No definite plans in the works yet, but we can't buy the tickets until Sept. anyway. One of the mysteries of Travel Agents.

Angel Insley was sent here on a week business trip July 13-16. After which she stayed on as a tourist for a bit. She stopped in Nagoya for 3 days and then came here Sun. afternoon. It was somewhat of a surprise. We knew she was coming, but not exactly when. She had our number, but couldn't figure out which part of it to use. The area code is slightly different if your calling from overseas rather than in the country.

We hit a few of the typical tourist spots: Osaka Castle (it's really more of a museum) on Mon.; Nara's deer park on Tue. - Todaiji Temple (site of one of the two Great Buddahs), Kasaga Shrine, a few other minor temples and a huge herd of deer are in the park area and all within walking distance of each other. They sell "deer cake" throughout the park. Angel wanted to see if the deer could recognize the biscuits if one just walk by nonchalantly, without offering them to the deer. They can. We were mugged by about 30 deer. Thankfully they're herbivors, so when they started nipping at anything and everything, no major damage was done. We never did figure out why the vendors are never attacked.

Wed. Yas took a half day off of work and we all went yachting. Angel being a pro, we figured it'd be no problem. However, the boat we rented was somewhat different from the kind she is used to. There was a fairly strong wind coming off of the mountains, blowing out across the lake. It was real easy for us to pull away from shore. Getting back however we knew would be more of a challenge. We decided to practice moving back inland before we got too far out on the lake. As soon as we turned back into the wind, we kept turning. But in the wrong way. We capsized. We righted the boat, but then there was the problem of getting back in. Angel, who was the only one who knew what to do, was hefted up first. While she was resetting the sails, Yas decided to let go of the boat (I'll never know why). So when the boat took off before the wind, Yas was left treding water. So to add to the excitement we got to try to swing around again to pick up Yas. After that, the rest of the trip was pretty uneventful.

That was Angel's last day here. Thur. she returned to the States from Osaka Airport. With heavy sighs, we said farewell for another eternity.

Other recent events.....It's IBM Japan's 50th anniversary. To commemorate this, they decided to give all of their full time employees a PC. Well, not exactly all of them. It's really a great marketing ploy. They had these JX PCs that were a complete failure in the market. This left 15,000 of them sitting in stock collecting dust. What can you do with that many PCs? Give them away, of course! But there are about 20,000 employees. So they had a drawing to pick

the lucky recipiants. The remaining 5,000 would receive a pair of coffee cups (with saucers, mind you) with "IBM 50th Anniversary" printed on the bottom. Of the PCs, there were 3 models - 2, 3, 4 - each being an upgrade of the previous one. The models were distributed by seniority, with the most advanced model going to those with the most seniority.

Lady Luck smiled on us, and we are to receive the model 3. As I said, there's a lot of good business in giving your own product to your own employees. Those with the PCs will now purchase additional hardware to upgrade the unit. None of the models comes with a printer. Not to mention the software you'll undoubtedly want to buy.

No time for mailing comments this time. I'll have to send this express anyway in hopes it arrives in time. But I will attempt to answer direct

Steve (#50) Ah, the microchip. One of my students from a few months ago was working on just that problem of cost evaluation. Apparently, his company (Mitsubishi) had no idea what the per unit cost is. Sounds like bad management, but what it involves is regular, excepted business practices that include things like government subsidies and what would amount to bribes and kick-backs in most other industrialized countries. Big Business is the main force behind the government, so the government supports Big Business. Industries are treated as Vestal Virgins - keeping foreign companies out and local prices artificially high. The yen, until recently, has also been kept artificially weak against other currencies.

Ultimately I think it comes down to a question of semantics. What we (Westerners) see as dumping, the Japanese see as just capitalizing as much as possible. Sort of along the lines of all's fair in love and war. The bottom line is, the Japanese will only make real consessions when forced to do so.

Dave L. (#50) My word processor is a Sanyo SWP-M2. Yes, it's 24 dot. Its functions aren't as limited as my ability to utilize them is. Since the manual and prompts are all in Japanese, I haven't quite figured out how to really use the thing. It does have various type styles - I have no idea yet how to produce them. I have semi-mastered the underline, though. There are 8 choices (decisions, decisions). The funny quotation marks are the quote symbols used when writing in kanji. This can also print out vertically as well as horizontally.

Guy W. (#50) Picking up Japanese can be done, contrary to popular myth. The hiragana you could probably master in a week - 10 chars. a day. Vocabulary in the comic books tends to be rather limited, so you could probably get at least the gist after a short time. For a "typical American" -- I don't know. I've never met one. Myself, I'm terrible at learning languages. I also don't study much. You might have better luck.

Since any given kanji can have multiple meanings and pronunciations, the hiragana tells you how to pronounce this particular one at this particular time, and therefore tells you which meaning to use.

Kiran (#50) Poverty is almost unknown here. Immediately after WWII there was a lot of it. Those who lived through those years are now the moms & dads of a new generation. They want to give their kids everything they never had -- and they do it with a vengence. It seems like everyone is wearing the latest fasions from Europe, has the every home convienience imaginable, and follows the latest fad.

There are homeless people, but there are almost no social welfare programs. So there are no statistics.

Rod (#50) Like everything here, videos are expensive. The low end of the scale is about ¥10,000 - usually for the mass-marketed tapes like Top Gun or Raiders. The high end goes up to as much as ¥80,000 or more. It sounds like

you are paying only the manufacturers cost.

Susannah (#51) The state of SF here is pretty much as your friend said. Almost anything is translated into Japanese, and almost nothing from it. Since I don't read Japanese, I can't really comment on the state of current literature. However, it's been my experience that the attitude towards SF indicates that "it's OK to read SF in high school or college, but once you're a company man, such things should be avoided". Some of the comic books have an SF theme - Giant Robots, etc. - but I don't know how the books are.

Greg (#51) I beleive that Teddy Ruxpin has all his friends here, but don't quote me.

And now it's time, to say good-bye, ...

Linda

Colorado Daily

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Serving the university community since 1892

...sagan

[FROM PAGE 1]

demonstrate that a new time has come," he said.

The two nations that have produced 60,000 nuclear weapons, a fraction of which could destroy the Earth, have a moral responsibility to step off the path toward annihilation, he said. Instead, Sagan concluded, they should "blaze the trail, on behalf of every human being, to Mars and beyond."

He was given a standing ovation.

Sagan blamed the U.S. government for rejecting Soviet overtures for cooperation in space exploration and for crippling NASA. The apparent U.S. concern that working with the Soviets in space would transfer technology to an adversary is misplaced, he said. Given Soviet advancements in space, he said, the United States would have more to gain. "This administration does not want to be seen as cooperating with the Soviets," he said.

An opportunity for Soviet-American cooperation approaches, space scientist Bruce Murray of the California Institute of Technology said Monday. The United States is planning the Mars "Observer" mission for 1992, at about the same time the Soviet Union is planning a Mars landing. Conceivably, each mission could be designed to support the other, Murray said. That sort of parallel but "symbiotic" exercise would benefit both nations while bypassing issue of technology transfer, he said.

Sagan's position that the Reagan administration is hastening the decline of the National Aeronautic and Space Administration was countered Monday by NASA Administrator James Fletcher, who insisted that the space agency has gotten strong support from the administration and can make progress within its budget.

But in Sagan's view, NASA lacks direction and goals. A campaign for Mars would restore both, he said, and would build on the public fascination and scientific interest in Earth's nearest planetary neighbor.

The Apollo program to place Americans on the moon was more a political goal than a scientific one, he said; it grew from American embarrassment about Sputnik and other Soviet advances in space. But at least it focused a national effort on an important goal. Since then, he continued, the United States has virtually abandoned exploration of space. Sagan criticized the space shuttle as an effort that has further weakened the nation's space program, and said the shuttle explosion was evidence of a decline that began years before.

"Astonishingly, NASA has been converted from the pride of American high-technology to close to being the butt of ridicule," he said.

Sagan and other conference speakers said a manned Mars landing is conceivable within the first decade of the 21st century. How to get there is a subject of great debate in the space science community. Some, including the national Space Commission last year, favor placing a base on the moon first, and using it as a jumping off point for Mars. That approach is also said to be favored in a report to be given to Fletcher in early August by astronaut Sally Ride, who has chaired a NASA panel charting directions for U.S. space exploration. Others, including Sagan, suggest Mars holds more significance to science.

Going back to the moon, he said, "could be more than a detour; it could be a trap."

That view was backed by one of the first men to visit the moon, Buz Aldrin. "We endorse a declaration for Mars," he said, speaking for the crew of Apollo 11. "The vast, unexplored, magnificent desolation beckons."

The Viking landers of 1976 gave clues to what may be found on Mars, though only two locations could be studied and neither craft carried surface rovers.

Daily Photo by Ed Kosmicki

The U.S. and Soviet governments, by joining a cooperative effort to land women and men on Mars, could defuse military tension and redirect defense industries to a productive cause, Carl Sagan told an audience of 1,000 at CU Sunday. His remarks came during The Case for Mars conference.

Sagan says Mars mission is alternative to WWIII

By STEVE RINEHART
Colorado Daily Staff Writer

The God of War could give Earthlings their best chance to avoid global destruction, astronomer Carl Sagan told an audience of more than 1,000 at CU on Sunday.

The planet Mars is more than an intriguing target for space exploration, a "world of wonders" where life may exist or have existed, a place of pink skies, sand dunes, towering volcanic peaks and raging windstorms, Sagan said in a speech to The Case for Mars conference; it presents an alternative to World War III. The U.S. and Soviet governments, by joining a cooperative effort to land women and men on the red planet, could defuse military tension and redirect defense industries to a productive cause, he said.

"There is a real and practical and sensible need for sustained cooperation between the United States and the Soviet Union, to culminate in the first footfalls of human beings on Mars," he said.

By cooperating in a push for Mars, the nations of Earth could "step back from the brink" of war, Sagan said. Speaking in a style that has become familiar to millions, the Cornell University professor drew a verbal picture of the high drama that would accompany Soviet and American cosmonauts and astronauts stepping from a capsule — together — onto the desolate Martian landscape.

"It would transfix the people of the world, and would

[TURN TO PAGE 2]

NASA head says U.S. definitely will go to Mars

The United States will send a person to Mars, declared NASA Administrator James Fletcher on Monday; the only question is "when?"

Fletcher, named to lead the space agency after the shuttle Challenger explosion in January 1986, did not affirm that Mars is the most immediate goal of the U.S. space program, noting that much scientific opinion favors establishment of a moon base first.

Still, he told The Case for Mars conference at CU, "We should go (to Mars), and I'm confident we will go." It could happen by the second decade of the next century, Fletcher said.

Advances must be made in propulsion, life-support systems, engineering and space medicine before people set out on a year-long journey to Mars, Fletcher said. "We need more information first."

Boulder County's Complete Newspaper
97th Year No. 126 ©

Daily Camera

July 20, 1987

U.S. urged to put man on Mars

Astronomer Sagan says NASA dying, has lost its focus

By JOAN ZALES
Camera Staff Writer

Imagine TV crews and hundreds of reporters and photographers covering the takeoff of the spacecraft with its international crew; the months-long space flight; and then the first landing of humans on another planet.

The cargo doors open and out come two flight commanders, one from the United States and one from the Soviet Union.

Visualize the commanders, "ankles tied together, gently hopping down" the spacecraft's steps and making a kind of "dual footprint in the sands of Mars."

So goes the Carl Sagan saga of a joint United States-Soviet Union manned exploration of Mars — a project Sagan believes should become a national goal.

Sagan is an internationally known astronomer, professor at Cornell University, president of the Planetary Society and creator of the award-winning TV series "Cosmos." He talked Sunday afternoon to a crowd of about 1,000 at the University of Colorado at Boulder at The Case for Mars III symposium.

He said there is a need for a sustained, cooperative project between the United States and the Soviet Union that will eventually put man on Mars.

Sagan painted a picture of Mars exploration giving a dying National Aeronautics and Space Administration a coherent goal that would "captivate the interest of the world," as the Apollo program did in the late 1960s.

A joint United States-Soviet Union project to put men and women on Mars would also bring cohesion to the two superpowers that could preclude the

(See U.S., Page 5A)

Camera staff photo by Vern Walker

SAGAN IN BOULDER: Carl Sagan speaks to about 1,000 people Sunday at The Case for Mars III symposium being held at the University of Colorado. Behind Sagan is a photograph of Mars.

FROM PAGE 1A

U.S. urged to put man on Mars

(From Page 1A)

necessity of a "Star Wars" defense system, Sagan argued.

Sagan said NASA, under the Reagan administration especially, but even before, "has been converted from the envy of the world into something close to the butt of ridicule." He said following the explosion of the space shuttle Challenger in 1986, future space explorations have been put on hold and consequently NASA's scientists have begun to drift away.

As further evidence of NASA's decline, Sagan noted that the United States launched "dozens" of manned and unmanned spacecraft during the 1960s and early 1970s. Since 1978, America has not launched one spacecraft to the moon or planets, he said.

Mars, rather than the moon, should be the target for future exploration because the moon is a "dull place," Sagan said.

The Mars of Sagan's description, however, is a "world of wonder," with pink skies, volcanoes three times the height of Mount Everest, and temperatures that vary from a "chilly New England October at the warmest, to colder than Siberia at the coldest." And the planet, believed to be the most like the Earth in the solar system, could provide scientists with data that might someday be helpful for Earth, he said.

Jointly working with the Soviets on project Mars would demonstrate to the world that a new time had come, Sagan said.

"We would use technology for good, not evil," Sagan said.

The first Case for Mars conference was held at CU in 1981, with few in attendance. The 1987 version has attracted interest from all over the country. During the five-day conference of talks, workshops and demonstrations, scientists will talk about bringing the human and robotic exploration of Mars to the stages of planning, research and design.

Saturday and Sunday's programs were free. Registration for the program today, Tuesday and Wednesday can be made in advance or at the door for $60 for professionals and $25 for students and educators. For information call 494-8144.

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U.S. RADIOISOTOPE THERMOELECTRIC GENERATOR SPACE OPERATING EXPERIENCE (JUNE 1961 — DECEMBER 1982)

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Abstract

Since 1961, the United States has used 34 radioisotope thermoelectric generators (RTGs), developed by the Department of Energy and its predecessors, as electrical power supplies in 19 space systems, including navigation and communications satellites launched by the Department of Defence and the Nimbus, Apollo, Pioneer, Viking, and Voyager spacecraft launched by the National Aeronautics and Space Administration. These RTGs have encompassed six design concepts spanning beginning-of-mission power ranges from 2.8 to 159.6 W(e). In general their performance exceeded operational requirements by providing electrical power at or above mission requirements and even exceeded the planned mission lifetime in many cases. The data derived from the diverse uses of these nuclear power sources demonstrate the capability of RTGs to function in a variety of space-mission environments in a manner that is reliable and safe.

Introduction

The use of nuclear sources of electrical power for space applications has been a key element of some of the more ambitious and spectacular astronautical undertakings of the United States. Nuclear electrical power provided the self-sufficiency that made many of these space missions possible (1).

Since 1961, the United States has successfully used 34 radioisotope thermoelectric generators (RTGs) as electrical power supplies in 19 satellites and spacecraft launched by the National Aeronautics and Space Administration (NASA) and the Department of Defense (DoD) (see Table 1). For this paper these RTGs have been grouped into six basic design concepts: SNAP-3, SNAP-9A, SNAP-19, SNAP-27, TRANSIT-RTG, and MHW-RTG. (SNAP is an acronym for Systems for Nuclear Auxiliary Power, and MHW-RTG stands for the Multihundred-Watt RTG.) The focus of this paper is on the power performance of the various RTG concepts.

The general technology trend for each of these RTG design concepts has been to improve generator performance, efficiency, and specific power. This has led to improvements in the technology of thermoelectric materials, from the lead telluride (PbTe) used in the first five RTG concepts to the silicon germanium (SiGe) used in the MHW-RTG and the RTGs being built for future space missions. Their performance has demonstrated that these nuclear power sources can be safely and reliably engineered to meet a variety of space-mission requirements.

SNAP-3B

The SNAP-3B generators (see Fig. 1) were used as supplementary power sources on the DoD Transit 4A and 4B navigational satellites launched in 1961. These RTGs were used to demonstrate the feasibility of operating nuclear power sources in space. Transit 4A was the first US satellite to use an RTG in space.

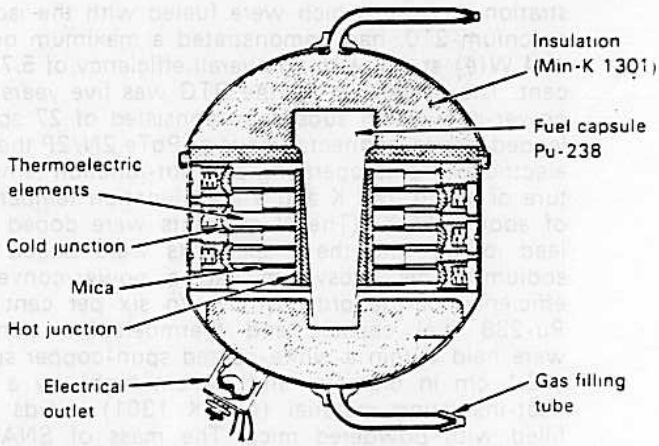

FIGURE 1
SNAP-3B RTG

The Transit 4A and 4B RTGs supplied power to the crystal oscillator that was the heart of the electronic system used for doppler-shift tracking. In addition, the RTGs powered the buffer-divider-multiplier, phase modulators, and 54- and 324-MHz power amplifiers. Tracking-station reception of 54- and 324-MHz coherent transmission at 100- and 50-mW output, respectively, complemented telemetry readout to confirm operation.

Each SNAP-3B generator was designed to provide an initial power output of 2.7 W(e). The heat source was approximately 52.5 W(t) of encapsulated plutonium-238 metal. Earlier RTG feasibility-demon-

*Office of Special Nuclear Projects US Department of Energy.

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TABLE 1 SUMMARY OF RADIOISOTOPE THERMOELECTRIC GENERATORS SUCCESSFULLY LAUNCHED BY THE UNITED STATES (1961-1982)

Power Source	Number of Power Sources	Initial Average Power per Power Source (W)	Spacecraft	Mission Type	Launch Date[a]	Initial Orbit	Status
SNAP-3B7	1	2.7	TRANSIT 4A	Navigational	29/6/61 (ETR)	~890 x 1,000 km 67.5°, 104 min	Satellite shut down but operational
SNAP-3B8	1	2.7	TRANSIT 4B	Navigational	15/11/61 (ETR)	~960 x 1,130 km 32.4°, 106 min	Satellite ceased transmitting
SNAP-9A	1	> 25.2	TRANSIT 5BN-1	Navigational	28/9/63 (WTR)	~1,090 x 1,150 km 89.9°, 107 min	Satellite ceased transmitting
SNAP-9A	1	26.8	TRANSIT 5BN-2	Navigational	5/12/63 (WTR)	~1,080 x 1,110 km 90.0°, 107 min	Navigational capacity ceased, but SNAP-9A telemetry operational
SNAP-19B	2	28.2	Nimbus III	Meteorological	14/4/69 (WTR)	1,070 x 1,131 km 99.9°, 107 min	Monitoring ceased
SNAP-27	1	73.6	Apollo 12	Lunar	14/11/69 (KSC)	Lunar trajectory	Station shut down
SNAP-27	1	72.5	Apollo 14	Lunar	31/1/71 (KSC)	Lunar trajectory	Station shut down
SNAP-27	1	74.7	Apollo 15	Lunar	26/7/71 (KSC)	Lunar trajectory	Station shut down
SNAP-19	4	40.7	Pioneer 10	Planetary	2/3/72 (ETR)	Solar system escape trajectory	Still operating
SNAP-27	1	70.9	Apollo 16	Lunar	16/4/72 (ETR)	Lunar trajectory	Station shut down
TRANSIT-RTG	1	35.6	TRIAD	Navigational	2/9/72 (WTR)	716 x 863 km 90.1°, 101 min	Still operating
SNAP-27	1	75.4	Apollo 17	Lunar	7/12/72 (KSC)	Lunar trajectory	Station shut down
SNAP-19	4	39.9	Pioneer II	Planetary	5/4/73 (ETR)	Solar system escape trajectory	Still operating
SNAP-19	2	42.3	Viking 1	Mars Lander	20/8/75 (ETR)	Trans-Mars trajectory	Lander shut down
SNAP-19	2	43.1	Viking 2	Mars Lander	9/9/75 (ETR)	Trans-Mars trajectory	Lander shut down
MHW-RTG	2	153.7	LES-8	Communications	14/3/76 (ETR)	35,787 km 25.0°, 1,436 min	Still operating
MHW-RTG	2	154.2	LES-9	Communications	14/3/76 (ETR)	35,787 km 25.0°, 1,436 min	Still operating
MHW-RTG	3	159.2	Voyager 2	Planetary	20/8/77 (ETR)	Solar system escape trajectory	Still operating
MHW-RTG	3	156.7	Voyager 1	Planetary	5/9/77 (ETR)	Solar system escape trajectory	Still operating

[a] Key to Launching Stations: ETR — Eastern Test Range; WTR — Western Test Range; KSC — Kennedy Space Centre

stration devices, which were fueled with the isotope polonium-210, had demonstrated a maximum output of 4 W(e) at 4 V with an overall efficiency of 5.75 per cent. The design life for the RTG was five years. The power-conversion subsystem consisted of 27 spring-loaded, series-connected pairs of PbTe 2N/2P thermoelectric elements operating at a hot-junction temperature of about 783 K and a cold-junction temperature of about 366 K. (The N elements were doped with lead iodide, and the P elements were doped with sodium.) This subsystem had a power-conversion efficiency of the order of five to six per cent. The Pu-238 fuel capsule and thermoelectric elements were held within a white-coated spun-copper sphere (12.1 cm in diameter and 14 cm high) by a rigid heat-insulating material (Min-K 1301); voids were filled with powdered mica. The mass of SNAP-3B was approximately 2.1 kg. The output of each generator was connected to a part of the satellite load through a DC-to-DC converter that increased the RTG voltage output. The Transit 4A generator (SNAP-3B7) operated with essentially a vacuum inside it to minimize conduction heat losses through the insulation. The Transit 4B generator (SNAP-3B8) was filled with an inert-gas mixture (krypton-hydrogen) to suppress the sublimation of the thermoelectric materials and to minimize the leakage of oxygen into the generator before launch (2-4).

Transit 4A has had the longest operating life of any satellite launched by the United States (4). As shown by the telemetered data in Figure 2, the generator parameters (load voltage, surface temperature) stabilized as predicted with an initial peak power of about 2.8 W(e). (The load-voltage peaks marked with an asterisk in Figure 2 were caused by load reductions during switching.) Although the main transmitter on Transit 4A failed after 17 days of operation (which prevented obtaining detailed data on the operation of SNAP-3B7), the 54- and 324MHz transmitters continued to send doppler signals that verified the continued operation of the SNAP-3B7 power supply (2, 4, 5). This satellite was still operational in 1976 despite the failure of the telemetry transmitter, the failure of the voltage regulator in the oscillator circuit, and solar-cell degradation, which was reported to be very severe (3).

The initial peak power output of the Transit 4B generator was 3.1 W(e). This generator maintained continuous operation from 15th November, 1961, to 6th June, 1962, when two excursions from normal to zero power were observed (Fig. 2) as the satellite passed within range of a ground telemetry-receiving station. An analysis of the technical data suggested a capacitor failure some point downstream from the RTG — very likely in the power-conditioning subsystem (3, 4, 5). The solar cells subsequently experienced rapid degradation as a result of a high-altitude nuclear test conducted over the Pacific on 9th July, 1962. The satellite ceased transmitting on 2nd August, 1962. On 23rd March, 1967, a tracking station in Pretoria, South Africa, picked up signals from Transit 4B (initially at 150 MHz and later at 54 and 324 MHz). The satellite responded to numerous commands during April and May 1967 but finally ceased transmitting. The last reported signal was in April 1971 (4). An analysis of the satellite circuitry by the Johns Hopkins University Applied Physics Laboratory (APL), the builder of the satellite, concluded from the telemetry data that the RTG had to be functioning (6).

From the test experience with the SNAP-3B and later PbTe RTGs, two general modes for the degradation of generator power output were identified:

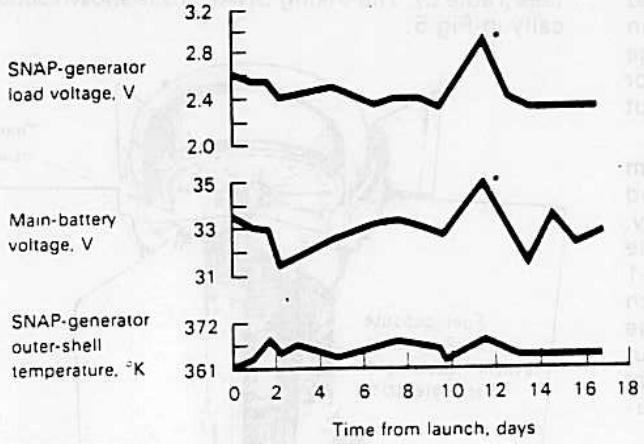

FIGURE 2(a)
SNAP-3B operating data telemetered from Transit 4A

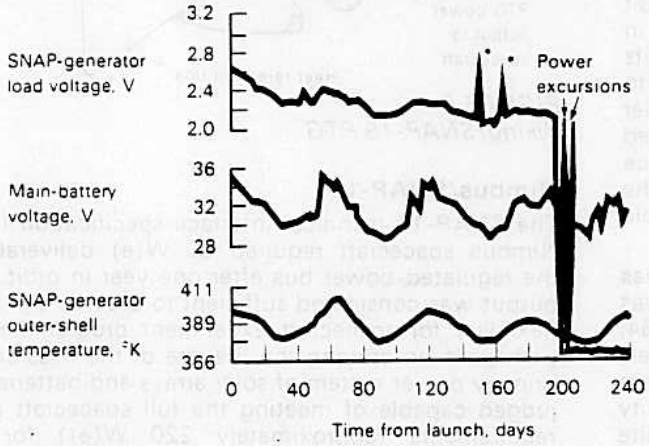

FIGURE 2(b)
SNAP-3B operating data telemetered from Transit 4B

1. Outgassing of the thermal insulation (H_2O from the Min-K insulation), which can lead to oxygen attack on PbTe elements and bonds. (The Min-K insulation can also experience structural instability caused by the loss of impurities during high-temperature service.)

2. Increases in generator internal resistance, which occur when the sublimation or loss of thermoelectric material at the hot junction leads to a reduced leg cross-section and hence a higher contact resistance. The second mode was judged to be the more probable, especially in the Transit 4A generator, which had essentially no inert fill gas (3). Research was subsequently undertaken to minimize the magnitude of these degradation modes.

SNAP-9A

The SNAP-9A generators (see Fig 3 and Table 2) were used to provide all of the electrical power for the DoD Transit 5BN-1 and 5BN-2 satellites. (Transit 5BN-1 was the first satellite to rely on an RTG for all primary power.) The RTG approach was selected because the RTGs are inherently radiation resistant, whereas the solar-cell power system of Transit 4B had been adversely affected by the 1962 high-altitude nuclear explosion (3). Each SNAP-9A was designed to provide 25 W(e) at a nominal 6 V for five years in space after one year of storage on Earth. The SNAP-9A thermal inventory of approximately 525 W(t) was supplied by Pu-238 metal encapsulated in a heat source consisting of six fuel capsules maintained in a segmented graphite heat-accumulator block. The total mass of the generator was about 12.3 kg.

The main body of the sealed generator was a cylindrical magnesium-thorium shell (22.9 cm in diameter and 21.3 cm high) containing 6 x 14 cm-wide heat-dissipating magnesium fins and 36 threaded holes. The surface of the generator had a sodium-silicate-zirconia coating with an emissivity on the order of 0.8. The coating also reduced the escape of the argon cover in space. Seventy pairs of series-connected PbTe 2N/2P thermoelectric couples were assembled in 35 modules of two couples each. The modules were sealed with O-rings into 35 of the threaded holes, with the 36th hole used as the mounting for the power-output terminals. A button-spring-piston arrangement on each couple ensured contact with the heat-source block. The heat-source block constituted the hot junction for the PbTe elements. The hot-junction temperature was calculated to be about 790 K in space at the beginning of life. (The corresponding calculated cold-junction temperature was 450 K.) Argon gas was used in each generator to inhibit the sublimation of the thermoelectric materials, and Min-K-1301 insulation was used to minimize heat losses. The use of furnace-brazed thermoelectric

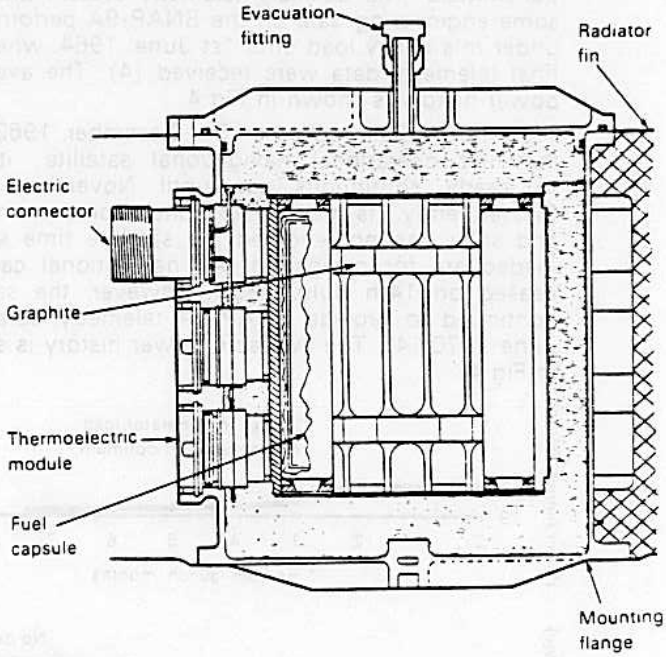

FIGURE 3
SNAP-9A RTG

TABLE 2 COMPARISON OF SNAP-9A AND SNAP-19 SYSTEM CHARACTERISTICS AT BEGINNING OF LIFE

Characteristic	SNAP-9Aa TRANSIT-5BN	Nimbus	SNAP-19 Pioneer	Viking
PERFORMANCE PARAMETERS				
BOM power output, W(e)	26.8	28.2	40.3	42.7
Load voltage, V dc	6.2	2.68	4.0	4.4
Hot-junction temperature, °K	790	800	785	819
FIN root temperature, °K	431	452	430	450
Thermal inventory, W(t)	525	628	648	683
Design life, years	5	1	3	2
Specific power, W(e)/kg	2.2	2.1	3.0	2.8
Efficiency, %	5.1	4.5	6.2	6.2
CONFIGURATION				
Height, cm	26.7	26.7	28.2	40.4
Fin span, cm	50.8	53.8	50.8	58.7
Number of fins	6	6	6	6
Housing diameter, cm	22.9	16.3	16.8	16.8
Mass, kg	12.3	13.4	13.6	15.2
PbTe thermoelectric material	2N-2P	2N-3P	2N TAGS-85	2N TAGS-85
PU-238 fuel form	Metal	PUO2 Microspheres	PMCb	PMCb

aThe SNAP-9A Data are nominal values. The Viking data were taken from the intial Lander checkouts made over 2 months after launch
bPlutonia molybdenum cermet

elements bonded with tin under a hydrogen atmosphere improved the efficiency of the generator and reduced the rate of power degradation caused by increases in internal electrical reistance (3). A DC-to-DC voltage converter increased the 6 V output of the generator to spacecraft levels, regulating five different output voltages to within ±2 per cent (3, 7).

One of the objectives of the DoD Transit 5BN program was to demonstrate the satisfactory operation and long-life potential of the SNAP-9A power supply. The Applied Physics Laboratory reported that the objective was fully satisfied. In fact, Transit "5BN-1 demonstrated the extreme simplicity with which thermoelectric generators may be integrated into the design, not only to provide the electrical power but also to aid in thermal control" (4). Some waste heat from the RTG was used to maintain electronic instruments within the satellite at a temperature near 293 K.

Transit 5BN-1, which was launched on 28th September, 1963, ceased transmitting on two telemetry bands on 22nd December, 1963, because of a short-circuit either in one of the satellite wiring harnesses or in the electronics. The excess load caused all outputs from the SNAP-9A converter to be depressed to levels that were insufficient to operate the doppler transmitters. The auxiliary telemetry system provided some engineering data on the SNAP-9A performance under this heavy load until 1st June, 1964, when the final telemetry data were received (4). The available power history is shown in Fig 4.

Transit 5BN-2, launched on 5th December, 1963, was the first operational navigational satellite; it was in nearly continuous use until November 1964. Subsequently, its memory exhibited some anomalies, and solar heating rendered the satellite time system inadequate for navigation. All navigational capacity ceased on 14th July, 1965; however, the satellite continued to provide SNAP-9A telemetry data until June 1970 (4). The available power history is shown in Fig 4.

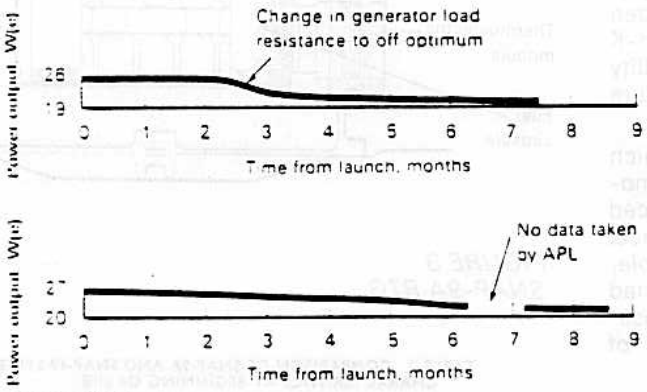

FIGURE 4
SNAP-9A power performance (smoothed data) as telemetered by Transit 5BN-1 (top) and 5BN-2 (bottom)

SNAP-19

The SNAP-19 technology-improvement programme built on the SNAP-9A development programme, with the SNAP-19B power system specifically designed for use on NASA's Nimbus weather satellites. The Nimbus SNAP-19 programmes was the first demonstration of RTG technology aboard a NASA spacecraft, and, as such, it developed the data and experience to support interplanetary missions using RTGs. Subsequent modifications were made in the SNAP-19B design to power NASA's Pioneer and Viking missions (see Table 2). The Viking SNAP-19 is shown schematically in Fig 5.

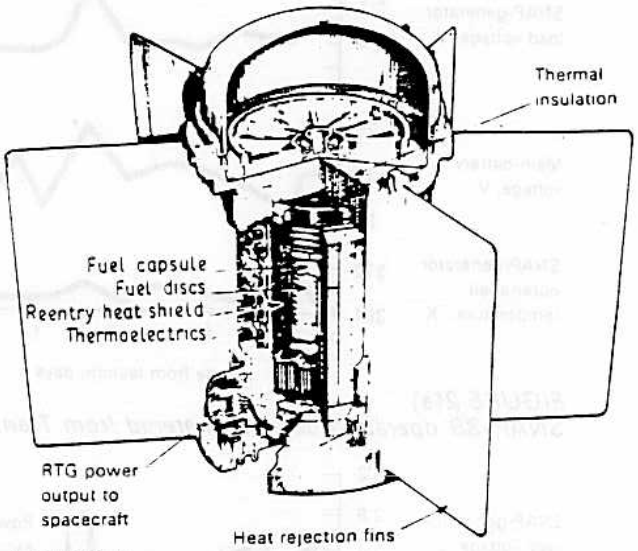

FIGURE 5
Viking/SNAP-19 RTG

Nimbus/SNAP-19

The SNAP-19 technical interface specification for the Nimbus spacecraft required 50 W(e) deliverable to the regulated-power bus after one year in orbit. Such output was considered sufficient to provide significant flexibility for spacecraft experiment programmes and perhaps even prolong the lifetime of the mission. The primary power system of solar arrays and batteries was judged capable of meeting the full spacecraft power requirements (approximately 220 W(e)) for only about one month.

To supply this power, two SNAP-19B RTGs, with higher fuel loadings than those of SNAP-9A, were used on the Nimbus III spacecraft. The RTGs were connected in parallel, with each RTG in series with its own DC-to-DC converter. Thus, a failure of either generator or converter would still permit the isotope power system to operate at half power. The thermoelectric elements were made of cold-pressed and sintered PbTe. Each RTG thermopile consisted of 90 PbTe 3P/2N couples distributed in six modules of three parallel rows of five couples each. The modules were connected in series and enclosed in a magnesium-thorium (HM-31) housing. The couples were metallurgically bonded to iron shoes and maintained under a compressive loading of some 89N by means of a spring-and-piston assembly. Min-K 1301 was used as the thermal insulation, and argon was used as the cover gas (initial fill pressure of 110 kPa) to reduce the sublimation of the PbTe material at its operating temperature and to minimize the diffusion of atmospheric oxygen into the RTG before launching. The RTGs were sealed with a circumferential Viton-A O-ring and bolted flange-seal arrangement (8). To meet the safety requirements associated with the higher nuclear fuel loading, the Pu-238 fuel was changed from a metal form to oxide microspheres.

Fig 6 shows the performance history of the two SNAP-19 RTGs on Nimbus III, after their launch on 14th April, 1969. The two RTGs produced 56.4 W(e) (49.4 W(e) usable) at launch and 47 W(e) one year later. This nuclear power comprised about 20 per cent of the total power delivered to the regulated-power

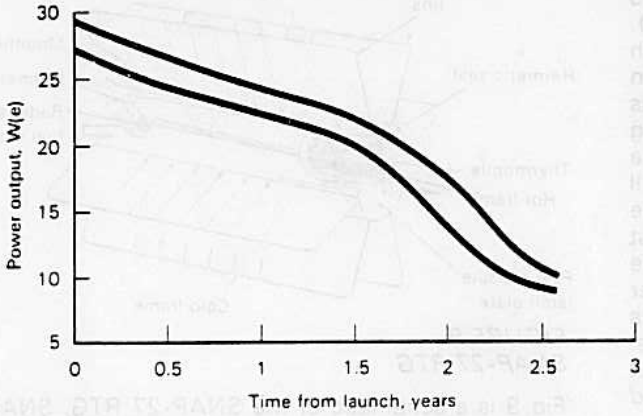

FIGURE 6
Nimbus III/Snap-19 power output (smoothed data)

bus during that time, allowing a number of extremely important atmospheric-sounder experiments to operate in a full-time duty cycle. The RTGs maintained the total delivered power above the spacecraft load line; without them, the total delivered power would have fallen below the load line about two weeks into the mission. The monitoring of Nimbus III was terminated on 22nd January, 1972, at which time the power output of each RTG was under 10 W(e) (9).

Overall, the RTG power decreased more rapidly than predicted on the basis of ground test data. This higher power degradation was attributed to the rate of argon leakage from the generator, which was higher than expected, and the replacement of argon by helium from the fuel decay. (Unlike the sealed fuel capsules used in the SNAP-3B and SNAP-9A RTGs, the SNAP-19B fuel capsule was vented into the generator.) The relatively low pressure of the lighter helium would not have protected against PbTe sublimation (10). Oxygen released from the PuO_2 fuel may also have contributed to the observed degradation by increasing the amount of oxygen available for attacking the thermoelectric elements and bonds (8). The design of subsequent RTGs was changed to reduce these sources of degradation.

Pioneer/SNAP-19

In order to satisfy the power requirements and environments of NASA's Pioneer Jupiter flyby mission, additional improvements were made to the SNAP-19B converter, heat source, and structural configuration. Specifically, a TAGS-SnTe/2N* thermocouple was designed to provide higher efficiency and improved longer term power performance. The electrical circuitry was modified to limit the magnetic field from the RTG to very low levels. The fill gas was a 75:25 helium-argon mixture, and a zirconium getter was added to eliminate any oxygen in the RTG. To reduce gas leakage further, the end covers were bolted and seam-welded to the cylindrical housing. The only leakage path to the outside environment was the O-ring seal around the RTG electrical connector, which served as a pressure-relief device for excess helium generated by the fuel decay (11).

Fig. 7 shows the power history of the SNAP-19/Pioneer RTGs, which were launched on 2nd March, 1972 (Pioneer 10) and 5th April, 1973 (Pioneer 11).

*The acronym TAGS is derived from the names of its major constituents: tellurium, antimony, germanium, and silver. TAGS is a solid solution of silver antimony telluride in germanium telluride. TAGS is an undoped inherent "P" material. The particular material used is sometimes referred to as TAGS-85, and it had a thin SnTe segment at the hot side. The N-leg was 3M-TEGS-2N(M) PbTe.

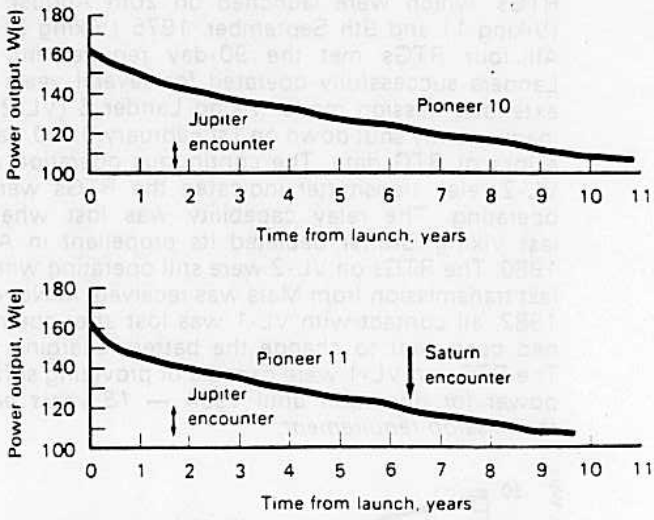

FIGURE 7
Power history of Pioneer/SNAP-19 RTGs (summed and smoothed data)

The mission requirement was that the four RTGs on each Pioneer spacecraft had to produce 120 W(e) total at the Jupiter flyby. The power output of the RTG system at the encounter with Jupiter was 144.0 W(e) for Pioneer 10 and 142.6 W(e) for Pioneer 11. The excellent power performance led to the estimate that the Pioneer RTGs could provide the minimum power requirements (90 W(e)) for a Saturn flyby. The Pioneer 11 RTGs actually provided 119.3 W(e) at Saturn, thereby adding another bonus to the mission. Both Pioneers are still operating 10 to 11 years after their launches, well beyond their mission design lifetimes, and are providing valuable information about the heliosphere. Pioneer 10 is now farther from the Sun than the planets Neptune and Pluto.

Viking/SNAP-19

The NASA Viking mission presented a different set of requirements, including high-temperature (400 K) sterlization, storage during the spacecraft's cruise to Mars, and, on the surface of Mars, ability to withstand the thermal cycling caused by the rapid and extreme temperature changes of the Martian day-night cycle. Each Viking Lander used two SNAP-19 RTGs modified to meet these requirements and the performance parameters shown in Table 2. Each RTG was to produce a minimum of 35 W(e) during the 90-day mission on the surface of Mars (the primary mission), which followed the 11-to 12-month cruise from launch. The two series-connected RTGs, which were the primary sources of power on each Viking Lander, supplied the energy for the scientific instruments and for recharging four nickel-cadmium batteries. The RTGs also supplied the Landers with thermal energy, which was used to maintain the Lander electronics at specified operational temperatures (12).

One modification from the Pioneer/SNAP-19 RTG was the addition of a dome reservoir. The initial fill gas for the converter was a 90:10 helium-argon mixture, while the reservoir was filled with a 95:5 argon-helium mixture. The purpose of this configuration was to permit a controlled interchange of gases in these two volumes to minimize heat-source operating temperatures up to launch while maximizing electrical output at the end of the mission (12).

Fig 8 shows the power history of the Viking SNAP-19 RTGs, which were launched on 20th August, 1975 (Viking 1) and 9th September, 1975 (Viking 2) (13). All four RTGs met the 90-day requirement. Both Landers successfully operated for several years in an extended mission mode. Viking Lander 2 (VL-2) was inadvertently shut down on 1st February, 1980, causing a loss of RTG data. The continuous operation of the VL-2 relay transmitter indicated the RTGs were still operating. The relay capability was lost when the last Viking Orbiter depleted its propellant in August 1980. The RTGs on VL-2 were still operating when the last transmission from Mars was received. In November 1982, all contact with VL-1 was lost after commands had been sent to change the battery charging cycle. The RTGs on VL-1 were capable of providing sufficient power for operation until 1994 — *18 years beyond the mission requirement.*

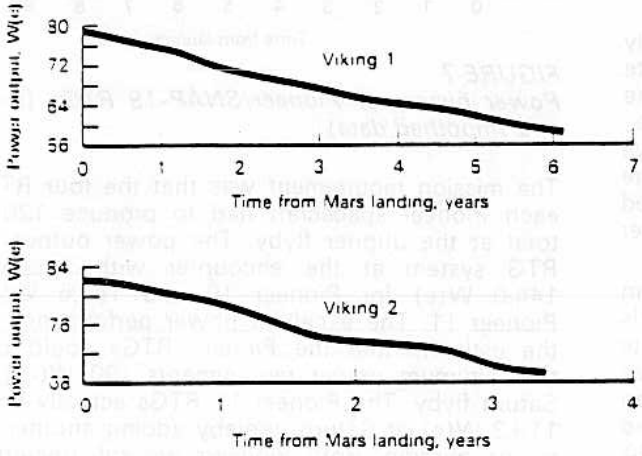

FIGURE 8
Power history of the Viking/SNAP-19 RTGs (summed and smoothed data)

Both the Pioneer and the Viking SNAP-19 RTGs demonstrated the operability and usefulness of RTGs in interplanetary spacecraft. All of these RTGs performed beyond their mission requirements. The principal contribution to degradation was judged to come from gas effects. It is evident from the outstanding performance data obtained from the Pioneer and Viking SNAP-19s that the changes made to the original SNAP-9A and Nimbus/SNAP-19 designs significantly minimized the degradation effects experienced in these earlier RTGs.

SNAP-27

The SNAP-27 RTG (14) was developed to power the experiments of NASA's Apollo Lunar Surface Experiments Package (ALSEP). The RTG design requirement was to provide at least 63.5 W(e) at 16 V DC one year after lunar emplacement. (In the case of Apollo 17, the requirement was 69 W(e) two years after emplacement.) The use of RTGs to power the ALSEPs was a natural choice because of their light weight, reliability, and ability to produce full electrical power during the long lunar night-day cycle. Since the ALSEPs were to be manually positioned by the astronauts, the designers took advantage of this assembly capability. The converter and the sealed-fuel-capsule assembly were kept separately in the Lunar Module and integrated on the Moon. This approach allowed optimization of the electrical, mechanical, and thermal interfaces of the two major hardware subsystems of the RTG.

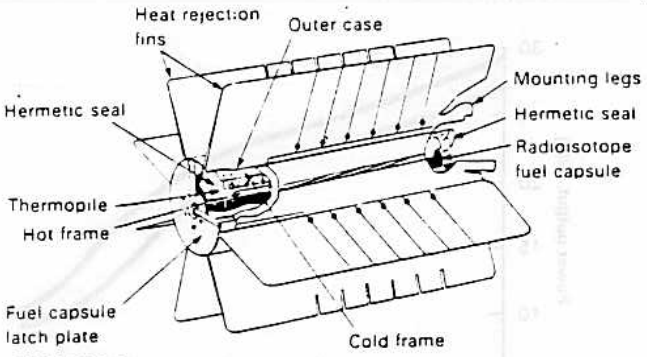

FIGURE 9
SNAP-27 RTG

Fig 9 is a schematic of the SNAP-27 RTG. SNAP-27 used 442 thermoelectric couples made of PbTe 3N/3P elements arranged in two series strings of 221 couples connected in parallel. Each element was preloaded into its hot button (shoe) by individual springs sized and shimmed to establish a bearing pressure of 1.03 MPa. The couples were hermetically sealed in the converter under an argon cover gas at 172 kPa and thermally insulated from each other by powdered Min-K. Heat from the fuel capsule, which was loaded with Pu-238 oxide microspheres and had a nominal rating of 1,480 W(t), was transmitted to the hot frame of the RTG by radiation coupling. Both the superalloy (Haynes-25) cladding of the heat source and the Inconel (IN-102) hot frame were coated with a high-emissivity (0.80 to 0.85) iron titanate (Radifrax) coating. Design analysis and ground tests indicated that the hot-junction temperature was about 866 K and the cold-side thermoelectric temperature was maintained at about 547 K in the normal operating mode (lunar environment). (The Apollo 12/SNAP-27 initial data indicated a lunar night-day variation of about 855 to 890 K at the hot junction and about 470 to 520 K at the cold junction.) Both the cold frame and the outer case were made of beryllium. Eight cross-rolled beryllium fins with a radial length of 12.7 cm were integrally attached to the outer case by brazing.

The converter was 46 cm high and 40 cm in diameter (including fins); together with a 3 m-long cable plus connector, it had a mass of 12.7 kg. The mass of the fuel-capsule assembly without the graphite lunar module fuel cask was about 7 kg. Each flight RTG was acceptance tested for not less than 500 hours, of which at least 200 hours was spent in a thermal-vacuum environment.

On 19th November, 1969, Apollo 12 astronauts Charles Conrad Jr and Alan L Bean assembled the first nuclear-powered ALSEP. Four additional SNAP-27-powered ALSEPs were subsequently emplaced on the lunar surface. The performance of the SNAP-27 RTGs is shown in Fig 10 (15). In each case all of the RTGs exceeded their mission requirements in both power and lifetime. This performance was achieved by the RTGs despite the variable duty cycle and the temperature extremes of the lunar day-night cycle. Through this performance beyond mission requirements, the SNAP-27 RTGs enabled the ALSEP stations to gather long-term scientific data on the internal structure and composition of the Moon, the composition of the lunar atmosphere, the state of the lunar interior, and the genesis of lunar surface features. All five RTG-powered ALSEPs were operating when NASA shut down the stations on 30th September, 1977.

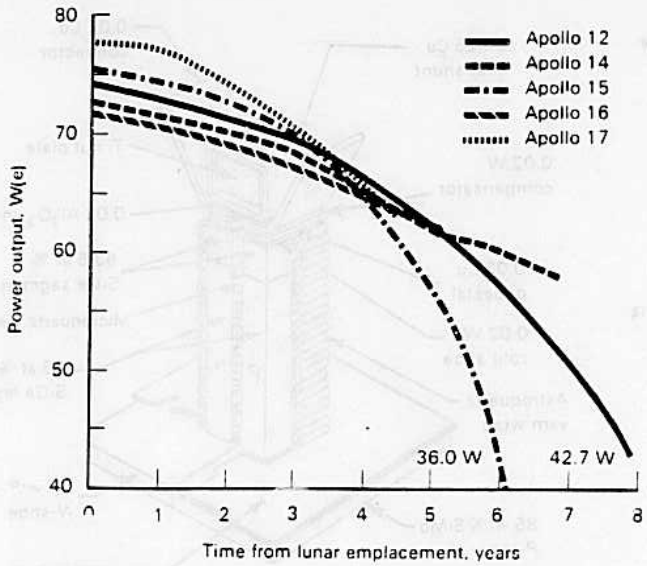

FIGURE 10
Power history of the SNAP-27 RTGs (smoothed data)

TRANSIT RTG

The TRANSIT RTG was developed specifically as the primary power for the DoD TRIAD navigational satellite, which was launched on 2nd September, 1972. Auxiliary power was provided by four solar-cell panels and one 6-Ah nickel-cadmium battery. The objective of the TRANSIT RTG programme was to produce an RTG capable of providing a minimum end-of-mission (EOM) power of 30 W(e) after five years at a minimum of 3 V. To do this, the 12-sided converter (see Fig 11) used lightweight PbTe thermoelectric panels (Isotec) that operated at a low hot-side temperature (673 K) in a vacuum, thereby eliminating the need for hermetic sealing and a cover gas to inhibit the sublimation of thermoelectric material.

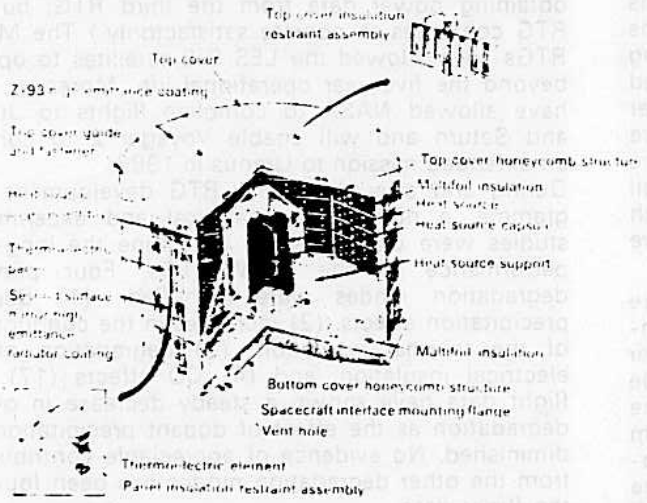

FIGURE 11
Transit RTG

The TRANSIT RTG was designed to be modular. The modular panel construction allowed increases or decreases in power as required by the mission, and the converter design was independent of the 855 W(t) heat-source configuration, which improved design and operational flexibility. Each of the 12 Isotec panels (14.5 by 36.3 cm) contained 36 PbTe 2N/3P couples arranged in a series-parallel matrix with four couples in a row in parallel and nine rows in series. The panels were structurally supported by 12 webbed magnesium-thorium corner posts with teflon insulators. The distance across flats was 61 cm. Each panel was designed to produce about 3.2 W(e) at about 0.5 V. Molybdenum-opacified paper washers were used to form a sleeve around each element to reduce thermal losses and to prevent potential sublimation of the thermoelectric material. The primary insulation consisted of 32 alternate layers of aluminium foil and aluminium-opacified quartz paper. A multifoil insulation blanket was also used in the top-cover and bottom-cover assemblies which were otherwise principally made of aluminium honeycomb and magnesium-thorium face sheets. The masses of the converter and the heat source were 5.98 and 4.2 kg, respectively. Including the titanium heat-source cage and support structure, the TRANSIT RTG had a mass of about 13.6 kg.

The short-term objectives of the TRIAD satellite were demonstrated, including a checkout of RTG performance; however, a telemetry-converter failure on 2nd October, 1972, caused a loss of further RTG telemetry data. The TRIAD satellite continues to operate normally and is providing useful magnetometer data, which testifies that the TRANSIT RTG is a dependable power source. Table 3 summarizes the available TRANSIT data (16)

TABLE 3 IN-ORBIT PERFORMANCE OF THE TRANSIT RTG

Performance paramter	Measured Predicted	First 20 days	25-30 days
Power output, W(e)	36.2±0.5	35.6±0.5	35.4±0.2
Average hot-cap temperature, K	673±4	674±2	673.6±0.7
Average cold-cap temperature, K	412±4	410±4	410.6±1.1
Load voltage, V	5.6±0.2	5.70±0.1	(b)
Load current, A	6.5±0.2	6.25±0.2	(b)

aAverage of day and night passes over the APL tracking station, including before and after spacecraft boom deployment and stablilization
bData not reported. A review of some raw data summaries shows the load voltage was about 5.58 V with a current of about 6.21 A.

Multihundred-Watt (MHW) RTG

The MHW-RTG (see Fig 12) was designed to provide a major increase in the power output of a space RTG (17). The DoD Lincoln Experimental Satellites 8 and 9 (LES 8/9) required 125 W(e) per RTG, with an output voltage of 30 (±0.5) V at the end of mission — an operational life of at least five years after launch. The NASA Voyager mission required 128 W(e) minimum per RTG, with an end-of-mission output of 30 (±0.5) V, or an operational life of at least four years after launch. To achieve these requirements, the MHW-RTG was equipped with a new heat source of 24 pressed plutonium oxide fuel spheres, each producing about 100 W(t). Electrical conversion was achieved through 312 silicon-germanium (SiGe) thermoelectric couples.

The use of high-temperature SiGe alloys as thermoelectric power-conversion materials was a direct outgrowth of spacecraft requirements for higher RTG power levels and lower RTG masses (ie, improved efficiencies). In general, a higher hot-side operating temperature means a higher efficiency, although the optimum temperature is dictated by the mission life (ie, minimizing sublimation). The cold-side temperature is optimized to obtain the desired power-to-mass ratio. To a first approximation, PbTe can be used from room temperature to about 900 K before materials properties and the figure of merit become concerns. The SiGe alloy can be used from room temperature to about 1,300 K and offers the potential of higher power with an improved efficiency. Furthermore, SiGe RTGs generally do not require an inert atmosphere for space operation because the temperatures (1,300 K or less) are normally below those at which sublimation presents a problem. (The use of multi-foil insulation

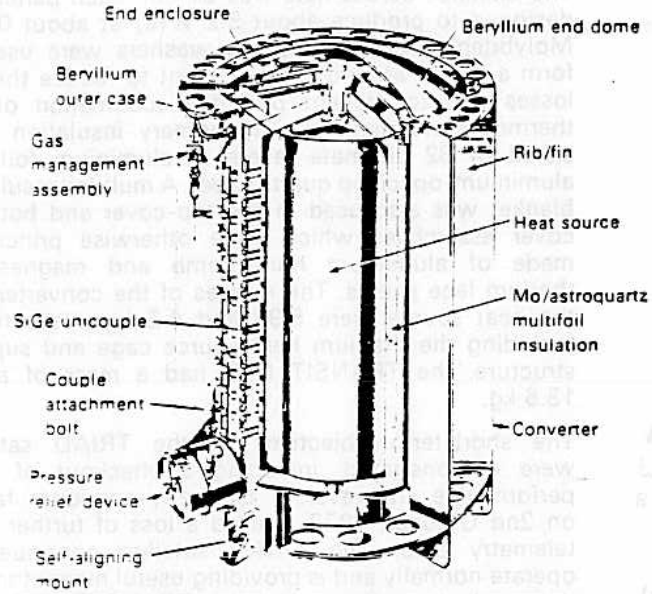

FIGURE 12
MHW-RTG

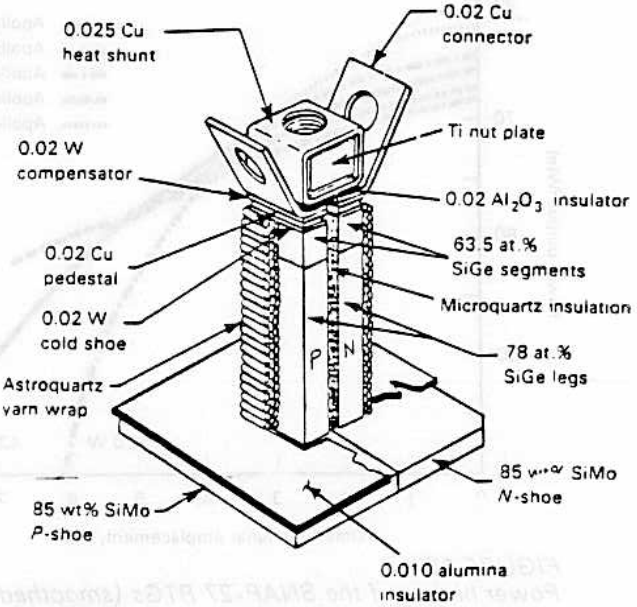

FIGURE 13
Silicon germanium unicouple (used on MHW-RTG and GPHS-RTG)

does necessitate sealing the RTG under an inert atmosphere on Earth to protect the molybdenum foil against oxidation.)

As shown in Fig 12, the converter consists of a beryllium outer case, which is the main support structure for the thermoelectric elements and for the heat source; end-closure structures that physically hold the heat source; thermoelectric elements; a multifoil (molybdenum-Astroquartz) insulation packet and a molybdenum internal frame; and a gas-management system. The gas-management system maintained an argon or xenon gas environment to allow partial power operation on the launch pad; full-power operation in space was effected by venting the gas through a pressure-relief device. (Several modifications were made for the Voyager mission: the forward ring of the converter case was reinforced for the increased loading predicted for the mission; an iridium canister and the associated pressure-maintenance device were deleted to reduce weight; and the mounting of the pressure-relief device was changed.) The overall diameter of the RTG was 39.73 cm, and its length was 58.31 cm. The average RTG flight masses were 39.69 kg for LES 8/9 and 37.69 kg for Voyager 1/2.

The 312 thermoelectric couples (see Fig 13) were arranged in 24 circumferential rows, each row containing 13 couples individually bolted to the outer case. The couples, which are called "unicouple assemblies", supported the insulation packet. The unicouple also contained the silicon-molybdenum (85 wt% Si) hot shoe to which the SiGe thermocouple legs were bonded. Two compositions of the SiGe alloy were used in the legs: 78 at .% Si for most of the length and a short segment of 63.5 at .% Si at the cold end of the couple. The purpose of using this segment with a lower silicon content was to match the thermal expansion of bonded parts. The N-type material was doped with phosphorus and the P-type with boron. The SiGe couple was bonded to a cold stack assembly of tungsten, copper, and Al_2O_3 parts that separated the electrical and thermal elements. Except for the lower-silicon segments and the hot shoes, a coating of Si_3N_4 was applied to the thermocouple legs to retard silicon sublimation.

A two-string, series-parallel electrical wiring circuit was used. The thermocouples were electrically insulated from the multifoil insulation by several layers of Astroquartz yarn tightly wound around the two SiGe legs of each couple and by an Al_2O_3 wafer behind the hot shoe. The design hot-junction temperature was 1,273 K (hot-shoe temperature 1,308 K) with a cold-junction temperature of 573 K. The design voltage was 30 V.

Figs 14 and 15 show the MHW-RTG power history from launch to 31st December, 1982, for LES 8/9 and Voyager 1/2, respectively (18). The peak initial power was 159.6 W(e) for RTG No 3 on Voyager 2. (An instrument failure on Voyager 2 has precluded obtaining power data from the third RTG, but the RTG continues to operate satisfactorily.) The MHW-RTGs have allowed the LES 8/9 satellites to operate beyond the five-year operational life. Moreover, they have allowed NASA to complete flights to Jupiter and Saturn and will enable Voyager 2 to conduct an extended mission to Uranus in 1986.

During and after the MHW-RTG development programme, a number of analytical and experimental studies were undertaken to determine the long-term performance of the MHW-RTGs. Four principal degradation modes were identified: (1) dopant-precipitation effects, (2) increases in the conductance of the thermal insulation, (3) degradation of the electrical insulation, and (4) CO effects (17). The flight data have shown a steady decrease in overall degradation as the effect of dopant precipitation has diminished. No evidence of appreciable contributions from the other degradation modes has been found in the flight data.

The successful performance of the MHW-RTGs has led to the use of the SiGe technology for the high-power (285 W(e)) General Purpose Heat Source RTG, (GPHS-RTG), which is to be launched in 1986 on the NASA Galileo Mission to Jupiter and the International Solar Polar Mission about the Sun (18). Table 4 illustrates the trends in RTG technology from SNAP-3B to GPHS-RTG, showing the overall steady progress to date.

Conclusion

RTGs have proved to be reliable, long-life sources of electrical power that have enabled the conduct of a

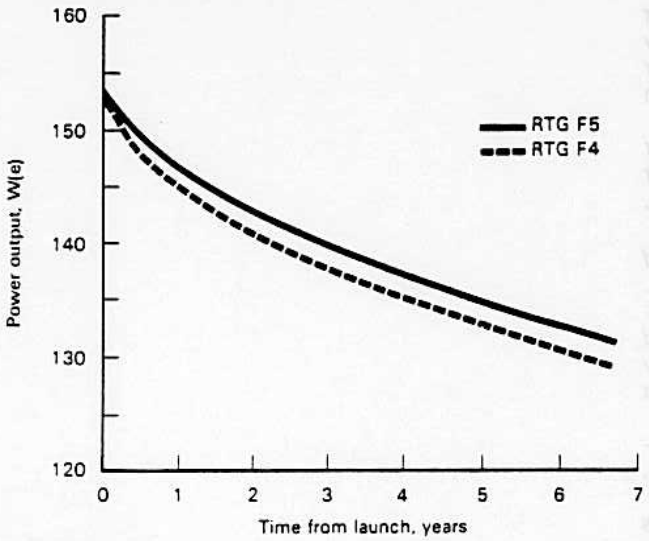

FIGURE 14(a)
Power history for LES 8 MHW-RTGs (smoothed data)

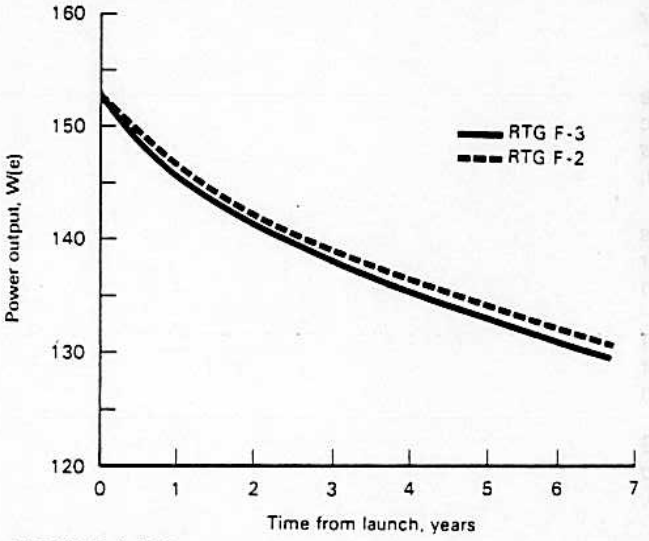

FIGURE 14(b)
Power history for LES 9 MHW-RTGs (smoothed data)

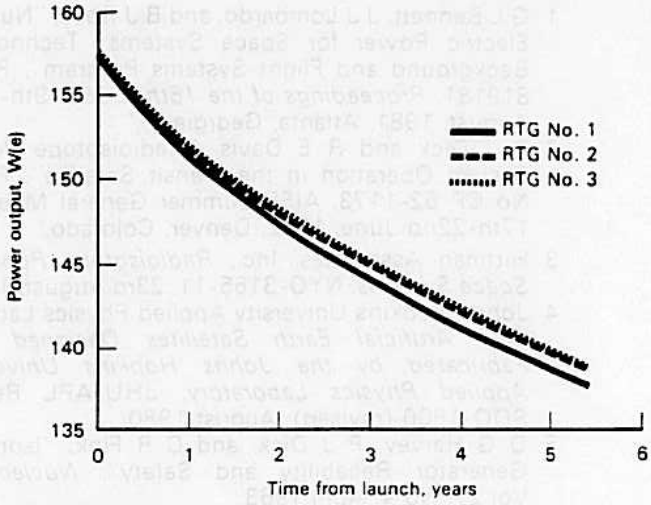

FIGURE 15(a)
Power history for Voyager 1 MHW-RTGs (smoothed data)

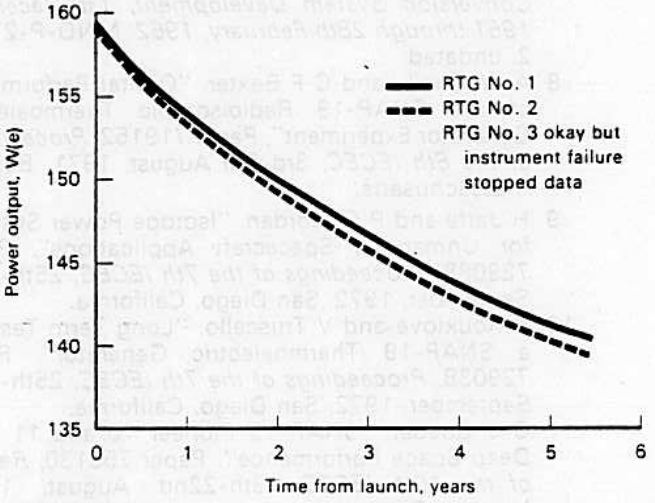

FIGURE 15(b)
Power history for Voyager 2 MHW-RTGs (smoothed data)

TABLE 4 TRENDS IN RTG TECHNOLOGY

Parameter	SNAP-3B	SNAP-9A	SNAP-27	TRANSIT-RTG	SNAP-19	MHW-RTG	GPHS-RTG
Mission	TRANSIT 4	TRANSIT 5BN	Apollo	TRIAD	Pioneer	Voyager	Galileo
BOM power per RTG, W(e)	2.7	26.8	73.4	35.6	40.3	158.0	292.0
Thermoelectric material	PBTE 2N/2P	PBTE 2N/2P	PBTE 3N/3P	PBTE 2N/3P	PBTE 2N/TAGS-85	SIGE	SIGE
PU-238 Fuel form	Metal	Metal	Oxide microspheres	PMC[a]	PMC[a]	Pressed oxide	Pressed oxide
Conversion efficiency, %	5.1	5.1	5.0	4.2	6.2	6.6	6.6
Specific power W(e)/kg	1.29	2.2	2.3[b]	2.6	3.0	4.2	5.2

[a]Plutonia molybdenum cermet
[b]The SNAP-27 specific power is shown with the fuel-cask mass included

number of important US space missions. In general, the RTGs, from SNAP-3B to the MHW-RTG, exceeded their mission requirements by providing power at or above that required and beyond the planned mission lifetime.

Acknowledgments

The authors acknowledge their indebtedness to all of the authors of IECEC papers on RTGs for much useful information. Special thanks for supplying information go to Paul J Dick of Teledyne Energy Systems (TES), John Dassoulas and Walt Allen of the Johns Hopkins University Applied Physics Laboratory (JHU/APL), G Stapfer of the Jet Propulsion Laboratory (JPL), C E Kelly of the General Electric Company Advanced Energy Programs Department (GE/AEPD), Frank D Postula of GA Technologies, Inc and E A Skrabek of Fairchild Industries. The authors acknowledge with thanks the contributions made to the US RTG program by members of the staffs of GE/AEPD, TES, TRW, Gulf General Atomic, JHU/APL, NUS Corporation, Fairchild Industries, Battelle Columbus Laboratories, Thermo Electron Corporation, 3M Company, JPL, RCA, Mound Plant, Savannah River Plant and Laboratory, the Los Alamos National Laboratory, the Oak Ridge National Laboratory, Sandia National Laboratories, the Ames Laboratory and the associated Department of Energy Operations Offices.

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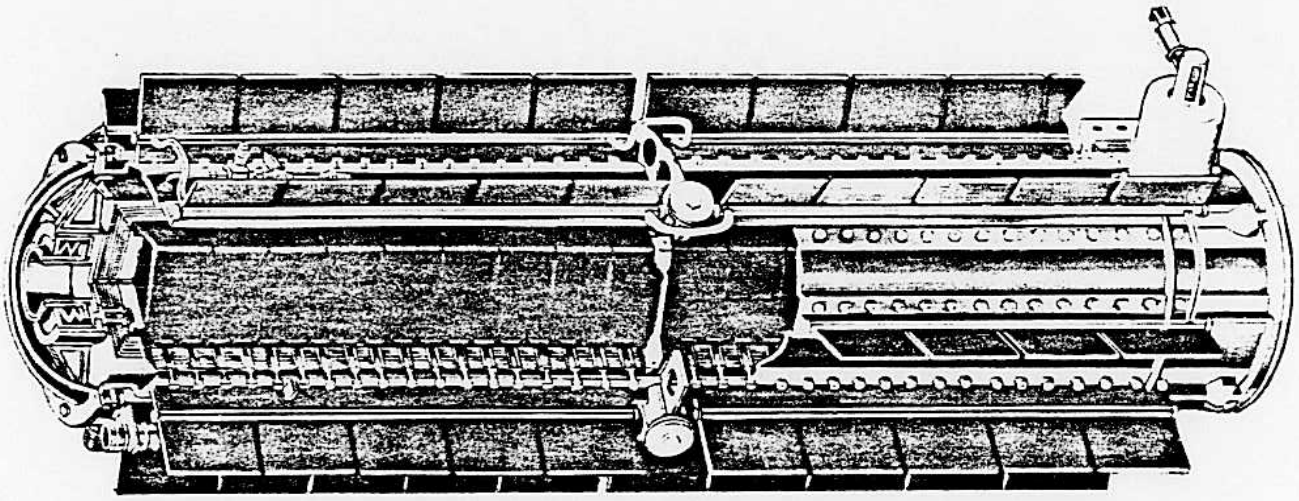
GENERAL PURPOSE HEAT SOURCE - RADIOISOTOPE THERMOELECTRIC GENERATOR



GENERAL PURPOSE HEAT SOURCE - RADIOISOTOPE THERMOELECTRIC GENERATOR ... POWER FOR GALILEO AND INTERNATIONAL SOLAR-POLAR SPACECRAFT

The General Purpose Heat Source nuclear powered electric generator is the latest in a series of nuclear power sources developed for space applications by the United States Department of Energy. Two General Purpose Heat Source generators, technically called radioisotope thermoelectric generators, will provide the electrical power for the Galileo spacecraft to be launched from the Kennedy Space Center, Florida, on the Space Shuttle in the Spring of 1986. In addition, one of these electric generators will power the International Solar-Polar spacecraft, also to be launched on the Space Shuttle, which is scheduled for launch also in 1986.

Each of the General Purpose Heat Source generators will produce at least 250 watts of electric power continuously for a period of five years or longer. The generators will be fueled with plutonium-238.

The General Purpose Heat Source nuclear generator is the latest in a series of thermoelectric generators using a radioisotope heat source. Earlier generator devices powered the data gathering science stations set up on the moon by the Apollo astronauts. Radioisotope thermoelectric generators were used also on the Nimbus III observation satellite, on the two Jupiter fly-by Pioneer spacecraft, and on the two Viking Mars landers. Currently, nuclear electric generators are powering the two Lincoln Laboratory Experimental Satellites - LES 8 and 9 and the two Voyager spacecraft which encountered Jupiter and Saturn.

The new generator will provide double the electrical output of recently employed generators such as those used on the Voyager spacecraft. It's higher electric conversion efficiency provides the highest specific power in the lowest specific volume now available. The silicon-germanium thermoelectric material used in the generators can operate in a vacuum, which attribute eliminates the need for a long-life, high temperature hermetic seal for the generator. The Galileo spacecraft will be the first to use the new nuclear power system.

The continued development of a radioisotope thermoelectric generator has been a logical response to recent trends in space exploration of the outer planets. Missions to these planets cannot use solar arrays for power generation because the sun's energy in these remote areas is too low to be used in an array that is practical from a size and weight viewpoint. Instead, these missions must have a compact, independent, long-lasting, and reliable energy source. The General Purpose Heat Source generator has no moving parts; hence, there is a minimum potential for mechanical failure. The radioisotope fuel, plutonium-238, has a long half-life and is in the completely oxidized and biologically inert form. Because of the volumetric efficiency of the nuclear heat source, the overall electric generator is relatively compact with dimensions of 44.5 inches (113 cm) in length, 16.6 inches (42.2 cm) in diameter, and a weight of 122 pounds.

Each generator has two functional parts: the nuclear heat source and the thermoelectric energy converter. The heat source contains the nuclear fuel in the chemical form of plutonium dioxide which provides the thermal input to power the converter. Plutonium-238 is an attractive fuel because of its relatively long (87.8 years) half-life and low shielding requirements. During radioactive decay, plutonium-238 emits primarily alpha radiation, the nuclei of helium, which requires little shielding, along with the emission of neutrons and gamma radiation. The latter radiation is kept at relatively low levels by the minimization of isotopic impurities in the fuel.

Physically, the fuel is in the form of cylinders with nearly semicircular ends. The fuel pellets are encapsulated first in an iridium shell; two of the clad pellets are then encased in a relatively thick graphite shell which provides impact protection in the event of an inadvertent reentry of the heat source and converter into the earth's atmosphere. This assembly of the clad fuel and impact shell is designed to contain the fuel safely under accidental circumstances for at least one year. Two of the graphite impact assemblies are protectively packed into a parallelepiped aeroshell for reentry capability. These complete heat source modules have overall dimensions of 3.7 by 3.8 by 2.1 inches (9.4 x 9.6 x 5 · 3 cm) and produce a thermal output of approximately 250 watts initially. Eighteen of these modules are stacked within the thermoelectric converter to provide the required heat input.

At the start of the mission, the heat source will provide a thermal input of approximately 4410 watts. Electrical power can be drawn from the generator on the launch pad for prelaunch checkout activities, if required. During the prelaunch operations, an inert gas such as xenon is used to fill the converter to protect the internal components from oxidation. The available output voltage, 30 volts DC, stays constant throughout the mission, being regulated by spacecraft electronics. Once in space, the inert gas is vented, and the generator reaches an initial electrical power output of about 290 watts. Because the fuel is constantly decaying in thermal power, its temperature drops and the available wattage declines. After five years, around 250 watts are available.

The converter of the nuclear powered generator operates on the thermoelectric principle. Heat generated by the radiosotope fuel is converted into electrical energy by silicon germanium thermocouples. Five hundred and seventy six of these thermocouples are arranged in 16 circumferential rows, each row containing 36 couples. The thermocouples are formed into unicouple assemblies which are individually bolted to the converter outer case.

The key features of these unicouple assemblies are:

- The thermocouple legs which are made of two SiGe alloys - 78 atomic percent silicon for most of the length and a short segment of 63.5 atomic percent silicon at the cold end of the couple to provide better matching for thermal expansion of parts bonded to the heat shunt.
- The silicon-molybdenum hot shoes to which the thermocouple legs are bonded. Electrical current is conducted between unicouples by copper electrodes. A two string, series-parallel, electric wiring circuit is used, permitting continued operation if a thermocouple fails in either the open or short mode. The thermocouples are insulated by several layers of astroquartz yarn tightly wound around the two silicon germanium legs. The thermal insulation canister is comprised of multiple alternating layers of molybdenum foil and astroquartz cloth separators through which the unicouples are inserted; foil insulated end caps complete the assembly.

PROGRAM PARTICIPANTS

Advanced Energy Programs Department, General Electric Company, King of Prussia, Pennsylvania, designs, develops, and fabricates the GPHS-RTG for the Galileo and International Solar-Polar missions. AEPD-GE also fabricates the thermoelectric elements and assembles the converters.

Speedring Division, Schiller Industries, Cullman Alabama, performs the intricate machining of the aluminum outer shells for the converters.

AVCO Systems Division, AVCO Industries, Wilmington, Massachusetts, supplies the Fine Weave Pierced Fabric composite graphite material for the General Purpose Heat Source Components.

Sandia Corporation, a subsidiary of Western Electric, operator of DOE's Sandia Laboratory, Albuquerque, New Mexico, provides quality control and reliability monitoring for DOE on the GPHS-RTG program.

University of California, operator of DOE's Los Alamos National Laboratory, Los Alamos, New Mexico, designs and develops the General Purpose Heat Source and performs the safety test program for the GPHS used in the GPHS-RTG generator.

Union Carbide Corporation Nuclear Division, operator of DOE's Oak Ridge National Laboratory, Oak Ridge, Tennessee, fabricates the iridium sheet material and the Carbon Bonded Carbon Fiber components used in the General Purpose Heat Source.

Monsanto Research Corporation, operator of DOE's Mound Laboratory, Miamisburg, Ohio, fabricates the iridium clads used in the General Purpose Heat Source, assembles the GPHS into the generator, and performs the acceptance and qualification testing of the GPHS-RTG's.

E.I. DuPont deNemours and Company, operator of DOE's Savannah River Plant and Laboratory, Aiken, South Carolina, prepares the plutonium fuel, fabricates the fuel pellets, and encapsulates the pellets in the iridium cladding.

Fairchild Industries, Germantown, Maryland, provides technical review, monitoring and consultation to DOE on the GPHS-RTG program.

NUS Corporation, Germantown, Maryland, provides analytical consultation to DOE in nuclear flight safety and provides quality control and reliability surveillance for the program.

Applied Physics Laboratory, Johns Hopkins University, Silver Springs, Maryland, provides analytical reentry and nuclear flight safety consultation to DOE for the GPHS-RTG program.

Battelle Columbus Laboratories, performs heat source reentry analysis and tests and provides materials consultation and testing for Space Nuclear Programs.

The frame size on the film stock is determined mathematically during raster photography depending on the distance between the viewer and the image (the camera and the nearest object). The minimum camera-object distance is determined with the acceptable frame size on the film stock.

The energy of the laser pulse during the shooting of holographic films is determined depending on the film stock sensitivity and the object's area. The photographed scene size attainable with relatively low laser radiation energies is found. The laser power for the holographic projection is determined depending on the number of seats. It is shown that the laser power for projection puts practically no limit on the number of seats in the movie theatre.

The optimum laser radiation wavelengths are determined when the most exact color rendering in holographic cinematography is achieved. It is shown that the high quality of the colored image can already be obtained for three wavelengths.

As a result, one can obtain a holographic screen with high diffraction efficiency and with the acceptable noise level for a practically unlimited number of viewers.

The Experimental Holographic Movie System

The system worked out in 1981–85 consists of the following elements. A camera for photography on 70 mm holographic film stock with a frame size of 51 by 47 mm, with the interrupted film stock moving at a rate of up to 24 frames per second. The lens has a focal length of 150 mm and an aperture of 22 mm. One camera is made for photography with pulsed lasers and continuous lasers, the other for vacuum clamping of the film stock.

Two printers were developed to print copies of holographic films. In the first printer the original film and the holographic film stock are placed close to each other.

In the second printer the lens is placed between film stocks. The advantage of the second device is that it ensures reversal of the image and choice of the optimum ratio of the intensities of the object beam and the reference beam separately.

Two different projectors were developed. In the first projector lasers are used, in the second there is a mercury-cadmium lamp. Of course, the projector with the laser gives a larger depth of image sharpness, but it is more complex. The projector with the lamp is simpler and cheaper, but depth is low.

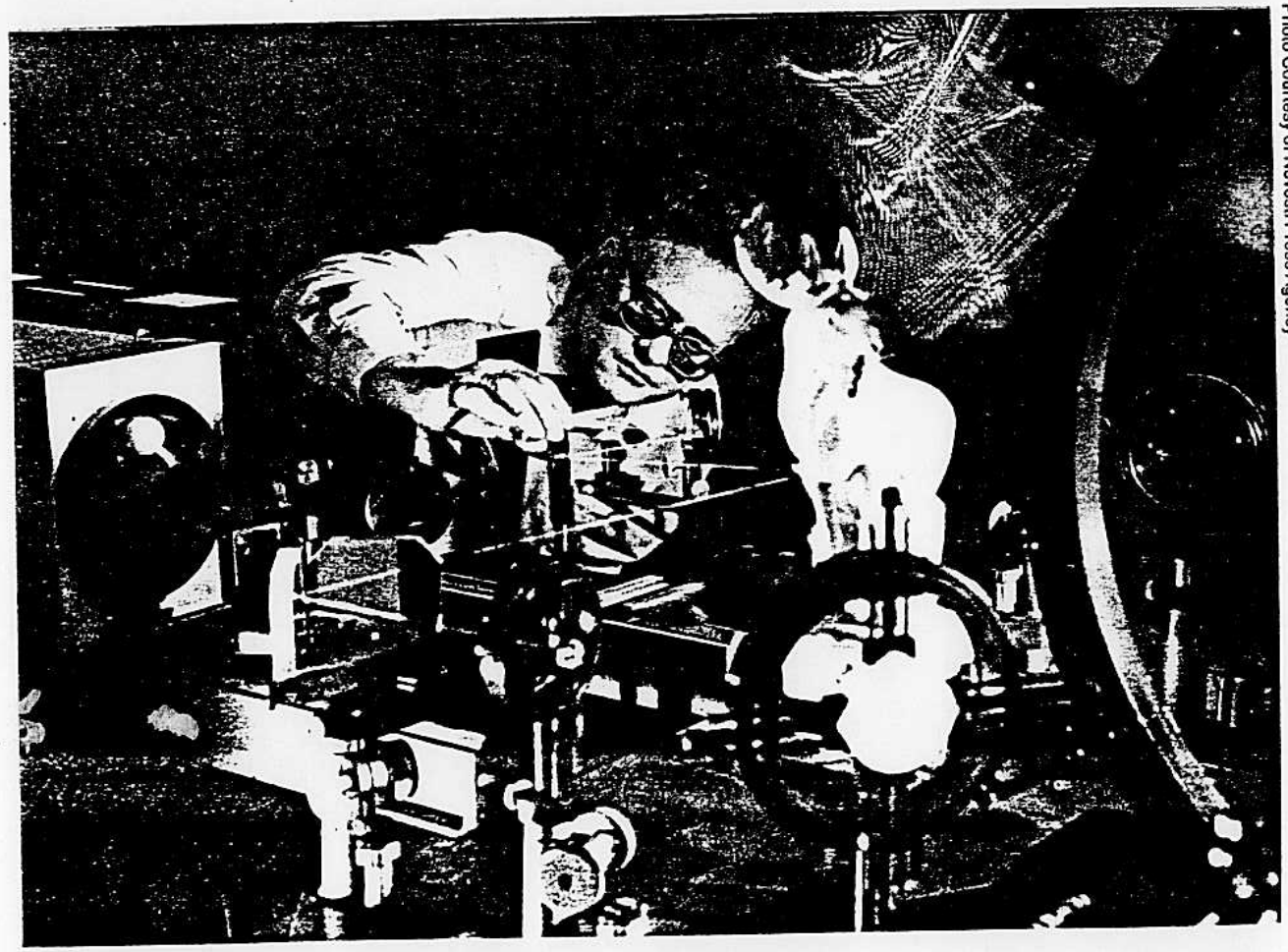


Photo Courtesy of Novosti Press Agency

At NIKFI, holography sector staffer Oleg Serov adjusting the experiemental laser.

The projector has a lens with a focal length of 250 mm and with an aperture of 200 mm.

There are three versions of devices for reproducing holographic movie image. In the first and second versions the projection is performed immediately on a multiplying point-focusing holographic screen 1×0.8 m in size. In the first version the holographic screen for monochromatic projection (0.578 mm in the yellow spectrum) has five viewing zones. In the second version the holographic screen for colored projection (0.647 mm in the red spectrum and 0.510 mm in the green spectrum) has two viewing zones.

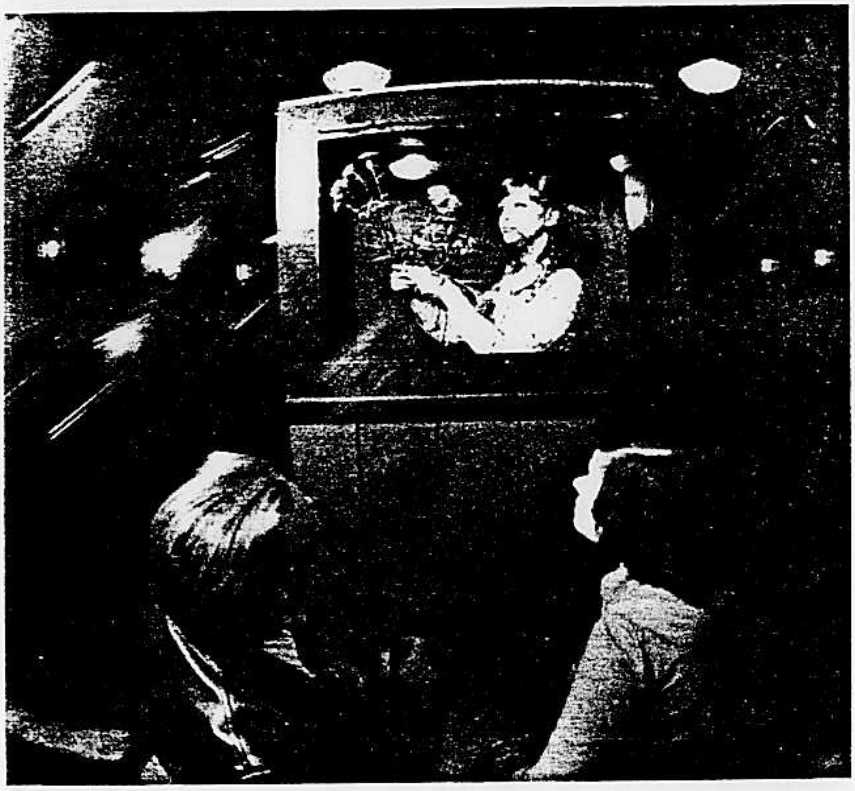
In the third version, projection is carried out on a mirror-film round vacuum screen 2m in diameter. The light beam from the cine-projector falls on the intermediate holographic screen. The screen reflects 24 separate beams, each of which is directed and focused on 24 mirror lenses. Beams reflected from mirror lenses are directed and focused on a large mirror-film vacuum screen. Beams reflected from the screen form 24 viewing zones in the movie theatre. In these zones viewers see three-dimensional images.

Several short experimental holographic films with an overall running time of about five minutes were made at NIKFI. The NIKFI two-layered film stock was used for colored holographic frames. The sensitivity of this 70 mm film stock in the red (0.647 mm) and green (0.514 mm) regions of the spectrum was about 5,000 erg/sq cm, the diffraction efficiency was 70 percent, the noise level was 0.007 (the ratio of the intensity of scattered light to the intensity of the resconstructing beam). In photography of colored miniature holographic films, use was made of Spectra Physics (model 171) lasers. A krypton laser (0.647 mm) was used when the power was 0.8 W and an argon laser (0.514 mm) when the power was 1.2 W.

Monochromatic frames were photographed on the Agfa-Gevaert 8E75 HD and 8E56 HD film stock. Use was made of a ruby (0.695 mm) and a garnet (0.530 mm) pulsed laser with a pulse energy of 0.1 j and with a pulse repetition rate of up to 24 per second.

At the Maxim Gorky Film Studios (cameraman Khristofor Traindofilov), preparatory work was carried out on a holographic film with a running time of 20 min.

Photo Courtesy of Novosti Press Agency



Experimental holographic films are shown on special screens like the one seen in this photo.

What are the possibilities of applying all these results? Technically it is possible to make miniature holographic films with a running time of 20-60 minutes, to set up holographic cine-sets with several seats (for instance, 25) and to open a holographic movie theatre with 100-150 seats.

With the accumulation of experience the second stage of the development of holographic cinematography can be expected: the shooting and presentation of holographic feature films. This calls for the creation of appropriate technical facilities: powerful pulsed lasers for colored photography, pulsed colored cine-photo holographic materials, the raster technique for obtaining colored three-dimensional images in non-coherent light.

Studies conducted under the guidance of Prof. Anatoly Roubinov have shown that to make and print holographic films, use can be made of lamp-pumped dye lasers and optimum wavelengths. A pulse radiation energy of 5-10 j can be obtained with a repetition rate of 16-24 pulses per second, with a coherence length of 10-20 m and a pulse width of the order of 1 m sec.

Research carried out under Lev Logak's direction has shown that in the near future it will be feasible to manufacture film stock for colored pulsed photography in laser light (red, green and blue).

Studies performed under the direction of the author of this article and Oleg Serov have demonstrated the technical possibility of manufacturing 3m×4m holographic screens for colored projection to 150-200 seats.

Dr. Victor Komar, Professor, is an Honored Scientist of the Russian Federation, Fellow of the Society of Motion Picture and Television Engineers (USA), Honorary Fellow of the British Cinematography, Sound and Television Society, Honory Member of the International Cinematographic Associations Union.

TECHNOLOGY FOR THE MENSCH

by Joachim Schűrmann, KA9WGP

as of: 530 West Walnut, Kalamazoo, Michigan 49007

Technology ...General news

Allright, I have done it. I got through the amateur radio license upgrade test. I am now holding a "General" license. I am in this for real.

A General class license holder must be able to read 13 words per minute morse code. This is a hard hurdle to take. The United States of America allow for radio amateur licenses with a code speed as low as five words per minute. However, this is an exception. In many other countries 13 words per minute is the minimum code speed to get any license at all. Great Britain for example, does not recognize any American license below the General class. With a less than General class American license, Italy will only allow operation in the VHF and UHF spectrum at less than ten watts power - that's walkie talkie stuff. Germany's regulations are similar.

I put a lot of time and motivation in the upgrade and I am glad that I made it. Before we leave the states I will try to go for the Advanced class license. Time is short, but the test is theory only. I think I have some chances to pass it.

Now that I have the new license, what am I doing that I could not do before the upgrade? Well, I can now do long distance, high power voice communication on some very desirable bands. However, this is difficult to do when operating portable out of an apartment building. As a result I am making very few contacts on those new bands. Instead I keep working ten meters which I learned to use and appreciate during the previous months. I learned how to be successful on this band and use the openings as they come. On the first of August I worked seven countries in two hours (telephony, USB), all of them south of Puerto Rico, since that is where my antenna is pointing: Uruguay, Chile, Brasil, Peru, Argentina, Ecuador, and Costa Rica. Some of these countries I never worked before; they have very few amateurs with suitable equipment. It is days like these that amateur radio is lots of fun.

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Radio propagation ...what is an opening?

I just mentioned that occasionally the situation is such that certain bands allow long distance communication. What does this mean? I will try to explain this for the interested reader.

Radio waves are part of the spectrum of electromagnetic waves. They are at the bottom end of the spectrum. At the high end of the spectrum we have light, X-rays and gamma rays. The entire spectrum has certain characteristics in common. The tendency to propagate in a straight line is one of them. You may have noted that normally light propagates in a very predictable straight line. You can gauge location, distances and speed of objects just by "sensing" the reflected light. Results are normally very accurate, but there are exceptions.

Exceptions to this rule are created when light travels through media of different and varying densities. The fish you see in a pond is not where you think it is. Given our "normal" experience, our brain will tend to extrapolate the position of the fish by assuming straight line propagation of light. Wrong in this case: the light is bent where the water meets the air. Variations of the same phenomenon reflect your image in a pond, make the surface of hot objects seem to vibrate, create Fatae Morganae and auroras. When mankind understood this handy phenomenon, mankind harnessed it and created telescopes, microscopes and cameras.

Radio waves work much in the same way. Bending, reflection and propagation is just more difficult to understand because we cannot experience it directly. Depending on the wavelength (i.e. frequency) of radiowaves, certain characteristics may be more pronounced than others.

For point to point communication beyond the radio horizon it is either necessary to bend the radio wave and force it to follow the surface of the earth or to reflect it somewhere in the atmosphere. At most wavelengths radio waves do a little bit of both. However, long waves rather bend along the curvature of the earth rather than being reflected by the atmosphere. Short waves are more easily reflected than bent. Microwaves do not like to do either. The secret of short wave communication is the reflection of electromagnetic waves in the atmosphere.

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The atmosphere consists of various layers. The layer we are most interested in for the purpose of this discussion is called ionosphere. Due to ultraviolet and particle radiation from the sun the ionosphere is electrically charged. The charge varies with the height from the ground, the time of the day, and the state of the sun. A solar flare will generally increase ionization.

There are different layers of ionized atoms in the ionosphere. At certain times certain layers will tend to absorb certain wave lengths of radio waves. At other times the same layers will bend or reflect radio waves.

If conditions are right, radio waves can bounce between the ionized layer of the atmosphere and the surface of the earth. At these times long distance point to point surface communication is possible. If this condition is achieved by a certain short wave band, we say that the band is "open".

If you listen to Radio Australia on 6060kHz in the U.S., the signal reaches you by bouncing back and forth between the surface of the earth and the ionosphere all the way from Shepparton, Australia, to wherever you are. Commercial short wave broadcasting stations use computerized models and a lot of experience to predict radio wave propagation and orient their antennas accordingly. Some of them also use a lot of power, sometimes as much as a small town, and can therefore afford some error in the prediction and still reach the targeted areas.

Radio amateurs play propagation mostly by ear. Literally. Listen to the band, see what is there and predict how far you can get. There are some beacons and fixed stations scattered through the bands that help with this task. There is also experience. For example: I know that at night and in the morning ionization of the atmosphere will not be strong enough to reflect a ten meter signal in any useful manner. During the day, reflection will be o.k., but certain layers will absorb much of the ten meter signal. As a result the power of a small household and/or a very good antenna may be needed to get any decent long distance communication on this band. But in the evening, when the sun gets ready to set, absorption will be minimal and reflection still quite good. This is the time for optimum propagation of ten meter signals. Quality of propagation

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may vary due to the sun activity and other factors. To verify how good propagation actually is at any given point in time, I will use beacons. There are handy beacons in Argentina and Brazil. By reading the strength of their signal I can determine how good propagation conditions are. If propagation conditions are very good, my signal may be able to bounce back and forth several times between the ground and the ionosphere without becoming too weak for reception. At this point I may be able to reach Uruguay and other remote places from our apartment in San Juan, Puerto Rico, with relatively low power and unsophisticated antennas.

There are other ways of propagation too, like ducting or scatter. The means are different, the results are more spurious, but the effect of carrying a radio signal beyond the radio horizon is the same.

Amateur Radio ...interesting encounters

Some of the most interesting contacts I had on the air are maritime mobile. There are quite some boats sailing the Caribbean. Some of these boats are equipped with amateur radio. On July 29 I got in touch with a sailboat on its way from Trinidad and Tobago to Venezuela. Its owner (Felix, DL4MCB/9Y4) is a retired gastronomer from Germany, planning to circumnavigate the world. He left Germany 2½ years ago and is now sailing along the coasts of South America visiting the various lands. We had a real interesting chat.

Technology ...car alarms

One more time I was awakened by wailing car horns sounding in response to the triggering of a burgler alarm. This kind of theft protection is real popular around here because car thefts are popular also. But what strikes me as disturbing is that these alarms can go on blaring for hours on end without anybody taking action. In fact, tonight the alarm kept howling from somewhere around four o'clock right into the morning. At some other point in time we noticed a car alarm going on for more than twelve hours until the battery was exhausted.

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Now, I ask you, if nobody takes action, what good is the alarm in the first place? Why do people still spend money on this kind of gadgets? Having grown up in Italy, I am probably more cynical than average: I always mistrusted alarm devices relying on the attention and action of bystanders, but I have never seen the message spelled out as clearly as here.

A movie ...some comments

I am not a big movie goer, but occasionally even I end up at the cinema - in particular if I get to go there with a beautiful and intelligent woman. Yes, in fact, most of the time Valli takes the initiative, kind of like: "Hey, let's go do something. Do you want to go to the movies or would you rather go to the movies?" Fine with me, let's do it.

Thus recently we went to see "The Untouchables" (in English with Spanish subtitles). I am not terribly impressed and I won't bore anybody with a movie review. Other people do that better. However, I will comment on one particular sequence.

Have you ever seen the movie classic "Battleship Potempkin" by Eisenstein? I have, many times. In Italy it's a cheapy television super late night feature on private commercial channels. Having done late evening shifts for a while, I got to see it quite often.

There are various famous sequences in this Eisenstein movie. One shows a baby carriage rolling down a large flight of stairs in the midst of a panicking crowd. This sequence is famous for the mobility of the camera, the depiction of details and the very skillful suspense building cuts (no, Hollywood did not invent the art of cutting, it just refined it).

I was very surprised to find this sequence in "The Untouchables" - no credits given. Uncanny similarity. This sequence also does not quite seem to fit well. One has the feeling that it is some kind of study or tribute. It is much too slowly paced for the movie and does not really support the story line. See for yourselves. It appears toward the end, when Elliot Nesst prevents Al Capone's bookkeeper from leaving Chicago. You'll recognize it when you see it.

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A book ...some comments

Again, I must give Valli credit for the initiative. Some weeks ago she threw a book at me:

> The NECEN Voyage
> by William S. Davis
> Wesley Publishing Company, (C) 1985

A very good choice for somebody who wishes to learn about computers. It also addresses a lot of social implications. It is a computer literacy textbook disguised as an SF novel.

The author assumes that a hacker took control of a vital government computer. The only way to regain control is to miniaturize a group of scientists and send them into the computer as bits of data. Much like in Asimov's "Fantastic Voyage" these scientists will travel inside the computer along the "arteries" in which the information flows and is processed. One should not expect scientific consistency in the miniaturization. There is none. The miniaturization is just a strategem that allows the author to explain how computers work.

The book is right up my alley. My last job was to keep the bad guys out of computers and find them when they were in. I can vouch for the correctness of most technical details. Some parts of the book I had to reread, which goes to show that there is always something new to learn, but every detail worked out allright.

Great book. Much old fashioned suspense and action. Reads like a spy novel but actually teaches science. I wish I could have learned political economy that way.

Cuisine ...about teas

The average american tea gives a very average taste. It typically comes in tea bags. Restaurants serve tea bags with pots of luke warm water. Customers are expected to soak the tea bags in the water provided. When the water in the pot is consumed, more warm water is added, thus extending the agony of the tea bags. I discovered that I fail to appreciate the American tea culture.

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I was brought up with teas. I don't claim to be a tea expert, but I don't go for a tinge of brown in a cup of warm water either. Discounting the homogenized, generalized, comprehensively and thoroughly user friendly tea brands in your corner grocery store, teas have character. And each tea can be brewed to suit a particular taste.

There are two aspects to preparing a tea: the choice of the tea and its preparation. At this point I like to briefly discuss some types of tea. I will talk about brewing techniques at some later time. This discussion is strictly subjective and the types of tea discussed are simply a choice of favourites. There is much more to teas than I can possibly mention here.

Teas are very much like wine: they are identified either by origin (Ceylon, Assam, Kenya, etc.) or by blend. The blend name sometimes reflects ethnicality (Russian, Persian, Ostfriesen, etc.); at other times it is simply the name of a successful marketing experiment or a company name (Salada, Fortnum & Mason Royal Blend, Earl Grey, etc.). Teas may be pure or spiced and scented. Earl Grey is a classic scented tea. There are also plenty of more recent spiced and scented creations on the American market.

The most failsafe and foolproof tea I can think of is Ceylon tea. Not too smooth, nor too spicy with a moderately average taste that should appease most taste buds. It can suitably be served with either lemon or cream and sugar or simply enjoyed as is.

A close second is the Earl Grey, for the lover of the slightly exotic taste. It is a rather bland and soft mixture of teas scented with Bergamott oil that adds an interesting flavour. This tea will not stand up to unusual brewing techniques. If brewed too long, the spicy flavour will fade. If brewed too strong, the Bergamott taste can easily turn intense and bitter beyond endurance. Earl Grey tea should be brewed strictly by the book, the British way. It should be served straight or with lemon. I also favour a touch of Demerara sugar. Serving Earl Grey tea with milk or cream is an obomination.

My personal choice is the Ostfriesen tea (East-Frisonian). As the name implies, this is an ethnical blend from northern

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Germany and east Holland. It is rather difficult to obtain in the States. Therefore, please allow me to mention some more commonly available substitutes. A good Assam will display many of the outstanding qualities of this tea. It will also be a trifle more tangy. Another alternative would be a Russian or Persian samowar blend. These teas are more bland than the Ostfriesen, but they are also more forgiving. However, it is slightly more difficult to brew them for flavour and character. In the unlikely, but extremely desirable event that you should be able to use Persian teas: beware, Persian teas are very generous. Use only a pinch of Persian tea where a tea spoon full of other tea may be indicated. The Ostfriesen teas and, to a certain extent, the above mentioned substitutes can be brewed to satisfy all possible taste requirements and degrees of strength. They rarely loose their character. Serve with lemon, cream, sugar, milk, or whatever other items you prefer. Also excellent with rum or cold, as iced tea.

Another favourite for special occasions are Kenya teas. Kenya teas are named after their origin, nevertheless they are blends, blends of teas from Kenya, that is. I discovered this type of tea through a fellow from London who, upon returning home, left his tea collection in Chicago for me to use. Since then I have tried different brands and found most of them delightful. I am currently using Harrod's Kenya tea. I find it most commendable. Kenya tea is tasty, spicy, tangy, and tends to be slightly bitter, therefore it is best consumed with cream and sugar. It is difficult and time consuming to brew this tea for smoothness, but it can be done. Kenya teas, like Persian teas, carry punch. A good Kenya tea is your choice of midnight special, whenever you have reasons not to sleep for a night. Two or three cups of solid Kenya tea enjoyed at bed time will easily carry you through the morning and more. On the other hand, a cup of moderately strong Kenya tea is a delightful introduction to a busy, active day.

This shall be enough about teas for the time being. In the future I will discuss brewing techniques. Good brewing techniques cannot redeem poor tea, but they do much to complement desired aspects of quality tea. Appropriate brewing techniques are therefore just about as important as the selection of a suitable tea blend.

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Operating mobile in Puerto Rico ...some pictures

Ready for the tropical sun...

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*** NEWSFLASH ***

On August 18th, 1987 I passed one more amateur radio examination. I am now qualified to operate in the Advanced class.

And she didn't even cry...

On Friday, August 15th, Chicago had a very bad rain, which ultimately built up to the second "century flood" in this century. Both me and Valli got stranded in various airports in the States, but let's not get into that. Rather, let me mention that we found our storage lockers to be located in the flood plane. Many of our worldly belongings are currently stored there. The content of one storage area was ready to be picked up by the movers. Everything was packed in cartons. The heavier items on the bottom, the lighter items on top. Valli's books were part of the heavier items. You know, Valli has quite a collection of books which she treasures very much. All the "junk" had been dumped before packing and the books stored were the good ones. Valli was very brave when we "processed" the cartons with her books: soaked dripping wet and mostly ruined. If I had my electronics flooded to oblivion I would probably have cried.

Driving into the sun...

I have always thought that the single most intense U.S.American stereotype is driving into the sun in a convertible on a six lane California highway while playing sixties rock on a HiFi sound system.

Today, August 20th, is our last day in Chicago and we almost lived up to this stereotype. Driving south on Lake Shore Drive on a splendid morning in a mushy rental car with all windows open while listening to "Little Old Lady in Pasadena" on FM "magic-one-oh-four" is as close as one gets in Chicago. Very nice, kind of deja-vu, and almost unreal... A great closing to a wonderful time in Chicago.

*** THE END ***